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CHARLES D. WALCOTT, DIRECTOR

THE

ILLINOIS GLACIAL LOBE

BY

FRANK LEVERETT

WASHINGTON
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ILLUSTRATIONS.

LETTER OF TRANSMITTAL.

University of Chicago, *July 15, 1898.*

Sir: I have the honor to transmit herewith the manuscript of a monograph on The Illinois Glacial Lobe, by Mr. Frank Leverett. This is one of a series of monographs which are in course of preparation on the glacial formations of the Northern States. My instructions when entering upon the work of the Geological Survey were to prepare a monograph on the terminal moraines which stretch from Dakota to the Atlantic. Soon after the inauguration of the work, however, it became apparent that the morainic systems were more amply and more intricately developed than had been at first apprehended, and that they, together with the associated glacial formations, were so highly diversified and so complicated that their elucidation could be reached only by prolonged investigation involving detailed work. It was therefore thought best to study the glaciated area by sections, and to publish the results of these partial studies as they might be ready, reserving for a later date the monographic treatment of the whole. Early in the preliminary work special attention was drawn to the Illinois glacial lobe, because its morainic ridges and its till sheets were very widely deployed and because its relations were such as to make it, in some sense, a key to the whole glacial series east of the Mississippi; and hence it has been given precedence.

Previous to my connection with the Geological Survey I had made sufficient reconnaissance of the area covered by this monograph to determine some of its salient features, and at the same time to disclose many other features which only patient and detailed study could elucidate. The results of these partial studies, combined with observations made during the first year of my connection with the Survey, were embraced in a preliminary paper published in the Third Annual Report. The more detailed work was taken up by Prof. R. D. Salisbury, Prof. L. C. Wooster, Mr. Frank

Leverett, and myself conjointly in 1886. Later the whole work was committed to Mr. Leverett, with the gratifying results of which this monograph is an expression. The relations of Mr. Leverett and myself during the progress of the investigation have been unusually intimate, and it has been a pleasure to contribute to the work such data and suggestions as my studies in this and other regions permitted. I trust that the monograph will prove a valuable contribution to the complex problem presented by the glacial series of the Northern United States.

Very respectfully, yours,

T. C. Chamberlin,
Geologist in charge.

Hon. Charles D. Walcott,
Director United States Geological Survey.

ABSTRACT OF VOLUME.

CHAPTER I. INTRODUCTION.—The Illinois glacial lobe formed the southwestern part of the great ice field that extended from the high lands east and south of Hudson Bay southwestward over the basins of the Great Lakes and the north-central States as far as the Mississippi Valley. It overlapped a previously glaciated region on the southwest, whose drift was derived from an ice field that moved southward from the central portion of the Dominion of Canada as far as the vicinity of the Missouri River. This southwestern part of the eastern ice field, being mainly within the limits of the State of Illinois, has received the name Illinois Glacial Lobe.

The results of earlier studies by Chamberlin, Salisbury, and others are noted, and the plan of investigation is set forth. A brief explanation of the method of numbering townships is presented.

CHAPTER II. PHYSICAL FEATURES.—The variations in altitude are set forth in a topographic map and also in tables, and the marked increase in altitude of certain parts of the region because of drift accumulations is considered. The conspicuous reliefs of the rock surface are briefly touched upon, and the preglacial valleys receive passing notice. Profiles and maps are extended across the bed of Lake Michigan as well as border districts, and the inequalities of the lake basin are briefly discussed.

CHAPTER III. OUTLINE OF TIME RELATIONS OR GLACIAL SUCCESSION.—A sketch of the major and minor divisions of the drift sheets and of the intervals between them is accompanied by a brief explanation of the basis for the classification adopted.

CHAPTER IV. THE ILLINOIAN DRIFT SHEET AND ITS RELATIONS.—The Illinoian is the most extensive drift sheet formed by the Illinois glacial lobe and receives its name because of its wide exposure in the State of Illinois. The evidence that the Illinoian drift sheet should be separated from the outlying and underlying drift and also from the Iowan drift is briefly set forth. The aspects of the Illinoian drift sheet are then discussed, its topography as well as its structure being considered. In connection with this drift sheet a very adhesive clay, known as "gumbo," which caps it, is described and the questions of its relation to this drift sheet and to the overlying loess are considered. A detailed description of the border of the Illinoian

drift sheet is then given, which is followed by a description of the moraines and other drift aggregations back from the border.

Remarkable instances of the transportation of rock ledges are noted. The striæ pertaining to this invasion are discussed in some detail. The effect of this ice invasion and its drift deposits upon the outer-border drainage is touched upon, but the detailed discussion of the influence of the drift upon drainage is deferred to a later chapter. The chapter closes with a discussion of the deposits which underlie the Illinoian drift sheet.

CHAPTER V. THE YARMOUTH SOIL AND WEATHERED ZONE.—A well-defined soil and weathered zone which appear between the Kansan and Illinoian drift sheets in the overlap of the latter upon the former are described, and sections are presented which show clearly the relations to these drift sheets. The amount of erosion effected during the interglacial stage is also considered. The name Yarmouth is taken from a village in southeastern Iowa, where the interglacial features were first recognized by the writer.

CHAPTER VI. THE SANGAMON SOIL AND WEATHERED ZONE.—Another well-defined soil and accompanying weathered zone which appear between the Illinoian drift and the overlying loess are described. The name Sangamon is applied because these features are exceptionally well developed in the Sangamon River Basin in Illinois and were there first noted by Worthen in the early reports of the Illinois geological survey.

CHAPTER VII. THE IOWAN DRIFT SHEET AND ASSOCIATED DEPOSITS.—The name Iowan was applied by Chamberlin to a sheet which is well displayed in eastern Iowa and which had been brought to notice by McGee. The chapter opens with the discussion of a drift sheet of a similar age which was formed by the Illinois lobe, its extent, topographic expression, and structure being considered. The relation of this ice lobe to the Iowa ice lobe, and the relation of each to the great loess deposit of the Mississippi Basin are then considered, after which the loess is discussed. The problem of the mode of deposition of the loess forms the closing topic.

CHAPTER VIII. THE PEORIAN SOIL AND WEATHERED ZONE (TORONTO FORMATION?).—The name Toronto formation, suggested by Chamberlin, for interglacial deposits exposed in the vicinity of Toronto, Canada, may prove to be applicable to a soil and weathered zone which appear between the Iowan drift sheet or its associated loess and the Shelbyville or earliest Wisconsin drift sheet which overlies the Iowan. Exceptionally good exposures of a soil and weathered zone at this horizon in the vicinity of Peoria, Illinois, make it seem advisable to apply the name Peorian, while the relations of the Toronto formation remain uncertain. Other exposures as well as those near Peoria are discussed. A marked interglacial interval between the Iowan and Wisconsin stages of glaciation may also be inferred by a comparison of the outline of the ice sheet at the Iowan stage of glaciation with that of the outline at the

culmination of the Wisconsin stage. It may also be inferred by a change in the attitude of the land, by which better drainage conditions were prevalent in the Wisconsin than in the Iowan stage.

CHAPTER IX. THE EARLY WISCONSIN DRIFT SHEETS.—The Wisconsin drift, named by Chamberlin from the State in which it was first recognized as a distinct drift, is characterized by large morainic ridges and comparatively smooth intervening till plains which have been thrown into two groups, known as the early Wisconsin and late Wisconsin. In the first group the moraines form a rudely concentric series, which are well displayed in the northeastern part of Illinois, but are largely overridden by the moraines and drift sheets of the later group in districts farther east. The outer border of the second, or late, Wisconsin group is so discordant with the moraines of the first group that there seems in this feature alone sufficient reason for separation.

The several morainic systems of the early Wisconsin group are taken up in succession from earlier to later, the distribution, relief, range in altitude, surface contours, thickness and structure of the drift, and the character of the outwash being considered. In connection with each morainic system the associated till plains are discussed, attention being given to the surface features and to the structure and thickness of the drift. In northern Illinois the several morainic systems are merged into a composite belt so complex that it is difficult to trace the individual members

The several moraines and their associated sheets of till do not appear to be separated by intervals so wide as are found between the Illinoian and Iowan or the Iowan and Wisconsin drift sheets. Indeed, instances of the occurrence of a soil or a weathered zone between Wisconsin sheets are very rare. There may, however, have been considerable oscillation of the ice margin.

CHAPTER X. THE LATE WISCONSIN DRIFT SHEETS.—The basis for separation from the early Wisconsin is first considered, after which the several morainic systems and their associated till plains are taken up in order as in the discussion of the early Wisconsin drift. An interpretation of the Kankakee sand area is attempted, though several questions connected with it still remain open. The chapter closes with a discussion of the striæ found within the limits both of the early and of the late Wisconsin drift.

CHAPTER XI. THE CHICAGO OUTLET AND BEACHES OF LAKE CHICAGO.—That a body of water once extended over the low districts bordering the southern end of Lake Michigan and discharged southwestward to the Des Plaines and thence into the Illinois River has been recognized since the early days of settlement, and several papers discussing the beaches and the outlet have appeared. The latter has long been known as the Chicago Outlet, because it led away from the site of that city. The lake has recently been given a name in harmony with that of the outlet (Lake Chicago.)

After reviewing the previous reports and papers, the Chicago Outlet is described in some detail. The several beaches of Lake Chicago are then taken up in order from highest to lowest. The chapter ends with a discussion of the present beach of Lake Michigan.

CHAPTER XII. INFLUENCE OF THE DRIFT ON DRAINAGE SYSTEMS AND DRAINAGE CONDITIONS.—It is shown that many drainage systems are entirely independent of the preglacial lines, while others are independent only in part, a considerable part of their courses being along the lines of old valleys. The development of drainage systems is shown to be much farther advanced on the Iowan and Illinoian drift sheets than on the Wisconsin. This is found to be due to differences in age and not to natural advantages for discharge. The Wisconsin is, on the whole, more favored by uneven surface for the rapid development of drainage lines than the Illinoian. The several drainage systems are discussed in considerable detail.

CHAPTER XIII. AVERAGE THICKNESS OF THE DRIFT IN ILLINOIS.—Illinois affords an especially good opportunity for the estimate of the thickness of the drift, because of the large number of well sections obtained, and because of the comparative smoothness of the region. The inequalities of the rock surface beneath drift plains may be estimated by the study of neighboring driftless tracts, as well as by borings and outcrops within the drift-covered area. There are thus two quite different methods by which the average thickness of the drift may be ascertained.

The first method here used is that of averaging the results of borings and outcrops. These are averaged in each township in which the distance to rock is known, and the results are then combined for the average of all the explored townships. Consideration is then given to the distribution of the explored townships in reference to drift plains and moraines and to preglacial uplands and valleys, and necessary corrections are made. By this method the thickness of the drift is found to be not less than 100 feet, and it may be 120 feet or even more.

The second method, based upon a comparison of the Illinois drift area with the neighboring driftless tracts, gives 129.3 feet as the average thickness, or slightly more than the highest results obtained by the first method. Combining the two methods, the average thickness of the drift of Illinois can be placed at not more than 130 feet and not less than 100 feet.

An attempt is made to estimate the part contributed by each ice invasion, but the data prove to be scarcely complete enough for a good estimate. It is found that the general thickness within the limits of the Wisconsin drift is 40 to 45 feet greater than in the portion of the State outside.

CHAPTER XIV. THE WELLS OF ILLINOIS.—This chapter aims to present all the reliable well records obtained within the State which throw light upon the deposits penetrated as well as upon the character of the water supplies. In addition to the wells which terminate in the drift there are included many which extend

deeply into the underlying rock formations. This necessitates a classification of the underground waters and a description of the several rock formations penetrated, including a discussion of the attitude of the strata. The essential conditions for obtaining artesian wells are considered, and also the relation of the drift to the ordinary wells. There is a brief discussion of gas wells, confined mainly to those obtained in the drift. A tabulation of sources for city water supply is then presented. after which there appears a detailed discussion of wells, taken up by counties.

CHAPTER XV. SOILS.—The sources of soil material are first discussed. An attempt is then made to classify the soils according to their origin. Eight classes are recognized, as follows: Residuary soils, bowlder-clay soils, gravelly soils, sandy soils, bluff-loess soils, silts slowly pervious to water, fine silts nearly impervious, peaty or organic soils.

THE ILLINOIS GLACIAL LOBE.

By Frank Leverett.

CHAPTER I.

INTRODUCTION.

The Illinois glacial lobe includes a portion of the great ice sheet which extended from the highlands east and south of Hudson Bay, southwestward across Michigan, the Lake Michigan basin, and Illinois, to the axis of the Mississippi Valley in southwestern Illinois and southeastern Iowa (Pl. I). It finds its natural limits on the northwest at the border of the Driftless Area of southern Wisconsin and northwestern Illinois. On the west it overlaps a region previously glaciated, but its extent there is readily determined, for it has usually a definite border in a belt of ridged drift. On the south and southeast it extends to the unglaciated tracts of southern Illinois and southern Indiana. From central Indiana northward it seems to have been merged with the eastern portion of the great ice sheet, except in shrunken stages. In the last stage here considered it extended but little beyond the borders of Lake Michigan and was then distinct from lobes to the east lying in the Saginaw and Maumee basins. The present report discusses the deposits made by the lobe south from the latitude of the Illinois-Wisconsin line, in Illinois, Indiana, and Michigan.

The drift deposited by this ice lobe has received considerable attention from the geologists of the several State surveys, and also from several students of geology not connected with official surveys. The early publications furnish numerous sections of the drift, of which mention is made below, which throw light on its structure and thickness. They contain

only occasional references to the topography of the drift surface. Apparently the first clear recognition of the import of morainic belts in this region was that by Prof. T. C. Chamberlin, who began his investigations in the Wisconsin Survey in 1873, and who in 1876 presented a map, before the Wisconsin Academy of Sciences, showing the distribution of the moraines of eastern Wisconsin. This was followed by one in 1878 showing moraines then recognized in the United States.[1] It soon became apparent to Professor Chamberlin that sheets of drift of widely different age occur, the later of which are characterized by stronger morainic lines than the earlier.

Prior to the recognition of the morainic belts and of drift sheets of widely different ages the published sections of the drift presented many puzzling features. But with this recognition the sections published by the early students became of service in making interpretations. The later students are thus able to build upon the work of the earlier. The disadvantages under which the earlier students worked, on account of the less complete knowledge of the glacial features, can scarcely be appreciated by those who are furnished with the present facilities for study. Any erroneous interpretations resulting from the restricted acquaintance with such features merit a most charitable construction. For example, the writings of Professor Worthen of the Illinois survey are full of the hypothesis of deposition of the drift by icebergs. The early reports of the geologists of the Indiana survey contain a similar interpretation of the drift. In the light of present knowledge of the moraines, with their attendant valley trains of gravel and other features demonstrating the presence of land ice, the iceberg hypothesis must of course be set aside, but this study of moraines has largely taken place during the fifteen or twenty years since the reports referred to were published.

The present report is an outgrowth of studies entered upon by Professor Chamberlin prior to the publication of his paper in the Third Annual Report of this Survey.[2] In that paper it is shown that the State of Illinois is traversed by several morainic lines lying outside the great moraine which is the theme of the paper. These lines, together with others not then

[1] Trans. Wisconsin Acad. Sci., Vol. IV (for 1876–77), 1878, pp. 202–234; with two maps.

[2] Preliminary paper on the terminal moraine of the second Glacial epoch, by Thomas C. Chamberlin: Third Ann. Rept. U. S. Geol. Survey (for 1881–82), 1883, pp. 291–402.

MAP OF THE GLACIATED AREA OF NORTH AMERICA.

(Modified from Upham's map Plate XVI Monograph XXV)

BY FRANK LEVERETT

1898

Scale, about 550 miles to an inch

known, have been mapped in detail and a large amount of data concerning them have been collected.

The detailed studies were begun in the spring of 1886, and the following statement concerning them was made by Professor Chamberlin in his report to the Director for the fiscal year 1886–87:

> Messrs. L. C. Wooster, R. D. Salisbury, F. Leverett, and myself have undertaken a work that is measurably new, though a part of the general plan of work previously inaugurated. In the region about the head of Lake Michigan and between it and the Erie basin is a tract which was invaded by successive glacial movements from both these great basins, these movements being more or less inharmonious and conflicting, resulting in exceptionally complicated phenomena. There arose from this a need for detailed study and the development of more refined methods of investigation than those demanded by the simpler drift tracts.[1]

During the field season of 1886 the study was extended out for a distance of 50 to 100 miles from the head of Lake Michigan in Illinois and Indiana, a division of the district being made so that each person worked a separate area. Since that season the field work has been largely carried on by Professor Salisbury and the writer, though Professor Chamberlin has constantly superintended the work and has from time to time visited the field. Professor Salisbury's work, since the first season, has been largely in southern and western Illinois, while the writer's has been mainly in the northern half of the State. During the autumn of 1892, however, the writer was detailed to collect soils and prepare a soil map of Illinois for the Illinois Board of World's Fair Commissioners. This study necessitated a reconnaissance of the southern portion of the State. This reconnaissance has been supplemented by more detailed studies in 1894 and 1896. The field work carried on by the writer in the region under discussion has been done mainly in the field seasons of 1886, 1887, 1892, 1894, 1896, and 1897. In the intervening years the same line of study was extended into bordering districts, and the broadening of the field has resulted in a better understanding of the features of this region. In the preparation of this report, and also throughout the field study, Professor Chamberlin has given constant advice and direction. The report really embraces the information obtained by Professor Chamberlin in his early reconnaissances, and the best fruits of his wider studies, and of the studies of his other associates, as well

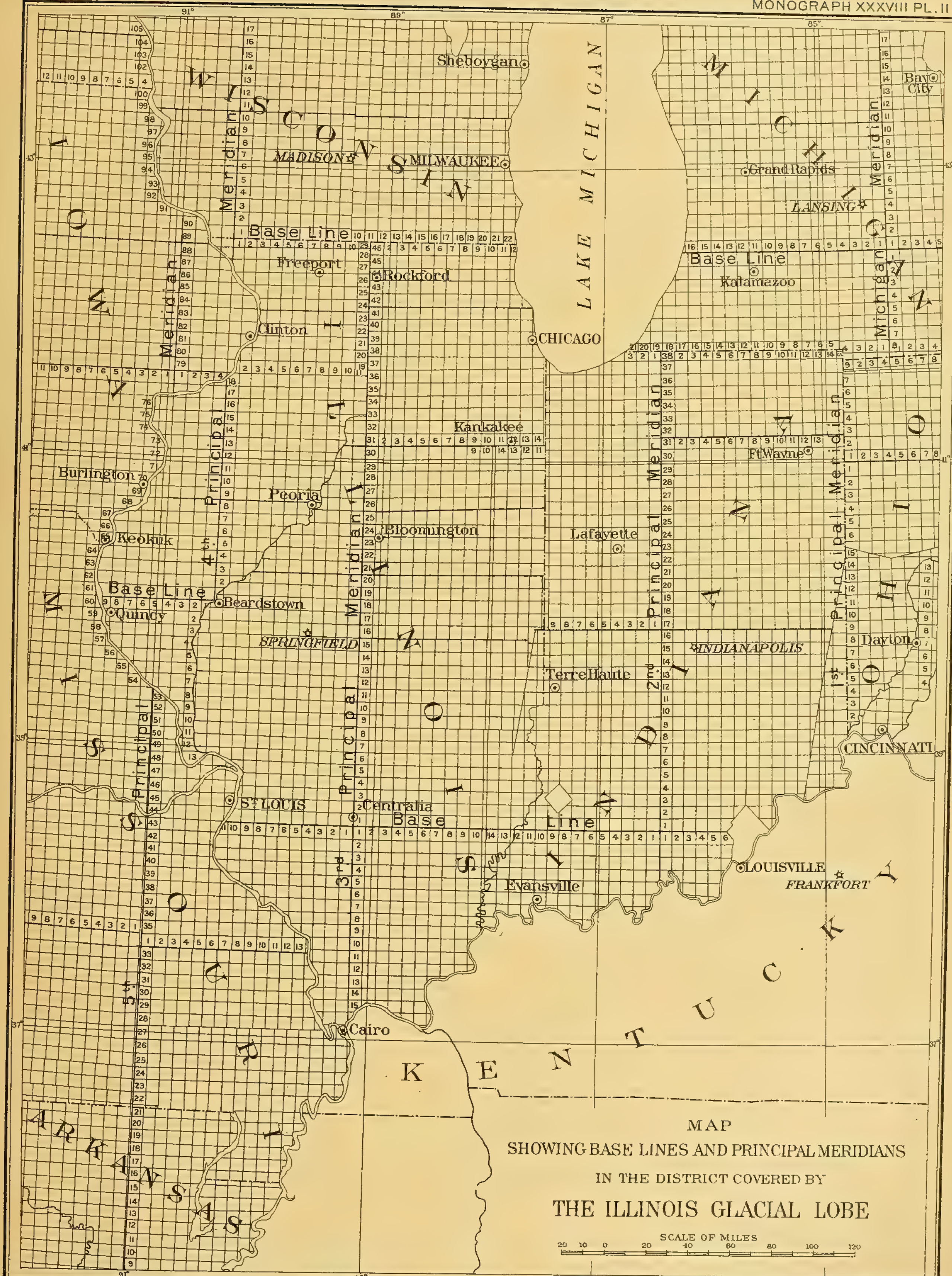
[1] Eighth Ann. Rept. U. S. Geol. Survey (for 1886–87), 1889, p. 141.

as the data directly obtained by the writer. It is with gratitude as well as with pleasure that this acknowledgment of indebtedness is made.

In this investigation there have been several distinct lines of observation, which supplement one another in throwing light upon the glacial succession. (1) The work began with a mapping of moraines, and this mapping has been carried to completion, i. e., each moraine has been followed throughout its entire course with sufficient zigzagging to learn its breadth and general features as well as the position of the crest. (2) With this study of the moraines there has been carried on an investigation of the stratigraphy of the drift, shown by well sections or other exposures, both artificial and natural. Several thousand well sections have been collected, many of which appear in tabulated form in this report. The mode of deposition of the glacial drift is such that a simple study of the drift sheets in a vertical series can not, in many cases, furnish index of the glacial succession. The mapping of the moraines has often aided greatly in working out the full glacial succession. (3) Coupled with the stratigraphic study and the mapping of the moraines there have been a few measurements and estimates of the relative amounts of erosion or other surface changes in the drift in different parts of the drift-covered area, a study which aims to throw light upon the relative ages of different drift sheets.

Since the townships are frequently referred to by number and range, rather than by the civil name applied to them, a brief explanation of the method of numbering townships in this region is here presented, together with a map (Pl. II) showing base lines and principal meridians. The explanation begins with the Second Principal Meridian adopted by the United States Land Survey, since the First Principal Meridian (which follows the State line of Ohio and Indiana) was not used as a basis for laying out any portion of the region under discussion.

The Second Principal Meridian leads north to south through west-central Indiana from the line of Michigan to the Ohio River, and is situated about 2 miles east of longitude 86° 30′ west from Greenwich. The base line crosses the southern portion of Indiana within 1 or 2 miles south of latitude 38° 30′. The townships are numbered both north and south from this base line. The State of Indiana only extends to T. 9 S., but reaches T. 38 N. of the base line. The ranges are numbered both east and west from the Second Principal Meridian. Those on the east extend to the State



MAP
SHOWING BASE LINES AND PRINCIPAL MERIDIANS
IN THE DISTRICT COVERED BY
THE ILLINOIS GLACIAL LOBE

JULIUS BIEN & CO. LITH. N.Y.

line of Indiana and Ohio, while those on the west have an irregular boundary. From the head of Lake Michigan southward nearly to latitude 41° the west boundary is at the State line of Indiana and Illinois, but south from this line it extends west into Illinois about 25 miles, being very near longitude 88°.

The Third Principal Meridian leads north from the mouth of the Ohio River to the Wisconsin line. It is about 8 miles west of longitude 89°. The base line is a direct continuation of the base line of the second meridian survey in southern Indiana. It enters Illinois from Indiana just north of the city of Mount Carmel and touches the south part of Centralia and Belleville, coming to the Mississippi River immediately below St. Louis. There are 17 townships south of the base line and 46 north of it. From the north line of the State south to the Illinois River at Peru the ranges lie entirely east of the Third Principal Meridian, but south from that stream the ranges are numbered both to the east and to the west. To the east they extend to the western limits of the survey based on the Second Principal Meridian; to the west they extend to the Illinois River above the mouth of that stream and to the Mississippi River south from the mouth of the Illinois.

The Fourth Principal Meridian leads from the Illinois River at Beardstown north to the Mississippi River about 8 miles above Rock Island, and is continued in western Jo Daviess County. The base line leads directly west from Beardstown to the Mississippi River, 6 miles above Quincy, and is situated about 2 miles north of the fortieth parallel of latitude. The townships south of the base line reach the number 14, while those north reach 29. The ranges are numbered both to the east and to the west of the principal meridian, north from Beardstown; south from that city they are numbered only to the west.

In Iowa and Missouri, together with several other States west of the Mississippi, the land surveys are governed by the Fifth Principal Meridian, which leads from the mouth of the Arkansas River north through eastern Arkansas, eastern Missouri, and eastern Iowa. The base line crosses central Arkansas, passing just south of the city of Little Rock. From this base line the townships are numbered to the south as far as the line of Arkansas and Louisiana. They are numbered to the north as far as the international boundary in western Minnesota and north Dakota. Eastern

Minnesota and Wisconsin are laid out from the Fourth Principal Meridian, the townships being numbered from the State line of Illinois and Wisconsin northward to the international boundary in Minnesota and Wisconsin, and to the line of Michigan and Wisconsin in eastern Wisconsin.

The State of Michigan is laid out from the Michigan meridian, which leads from Sault Ste. Marie south to the Ohio State line. The base line follows the parallel 42° 30′. The numbering of townships north from the base line harmonizes with those laid out from the Fourth Principal Meridian in Wisconsin and Minnesota. The ranges are numbered both to the east and to the west of the principal meridian as far as the limits of the State.

In each township there are 36 sections, numbered back and forth in tiers of six, the numbering beginning at the northeast and terminating at the southeast corner of the township.

CHAPTER II.

PHYSICAL FEATURES.

Before entering upon a discussion of the glacial deposits, the leading physiographic features of the region will be outlined. The region invaded by the Illinois lobe occupies the midst of the great interior basin which on the east rises to the Appalachian Mountains and on the west to the Rocky Mountains. The State of Illinois has the distinction of being the lowest of the North-Central States. Its mean elevation has been estimated by Mr. Henry Gannett to be about 600 feet above tide, while that of Indiana is 700 feet, Michigan 900 feet, Wisconsin 1,050 feet, Iowa 1,100 feet, and Missouri 800 feet.[1]

Including the south end of the Lake Michigan basin, the region covered by the Illinois lobe shows a range of not far from 1,200 feet, the bottom of the lake opposite Racine, Wisconsin, being at sea level, while the highest rock surfaces of Illinois covered by glacial drift are nearly 1,200 feet above sea level. It is not unlikely that glacial erosion and differential depression have increased this range, but there is reason to think that in preglacial times the lake basin was at least several hundred feet lower than the highest ridges of the border districts and that it had a controlling influence upon the course of the ice movement.[2]

The State of Illinois has been covered by a careful barometric survey conducted by Prof. C. W. Rolfe, of the University of Illinois, a survey which had for its object the preparation of a topographic model of the State for the Columbian Exposition. Professor Rolfe used as datum points the altitudes of railway stations which had been determined by surveyor's level. These are found at intervals so frequent in nearly every county of the State that there is but little room for error in his maps. He has exercised great

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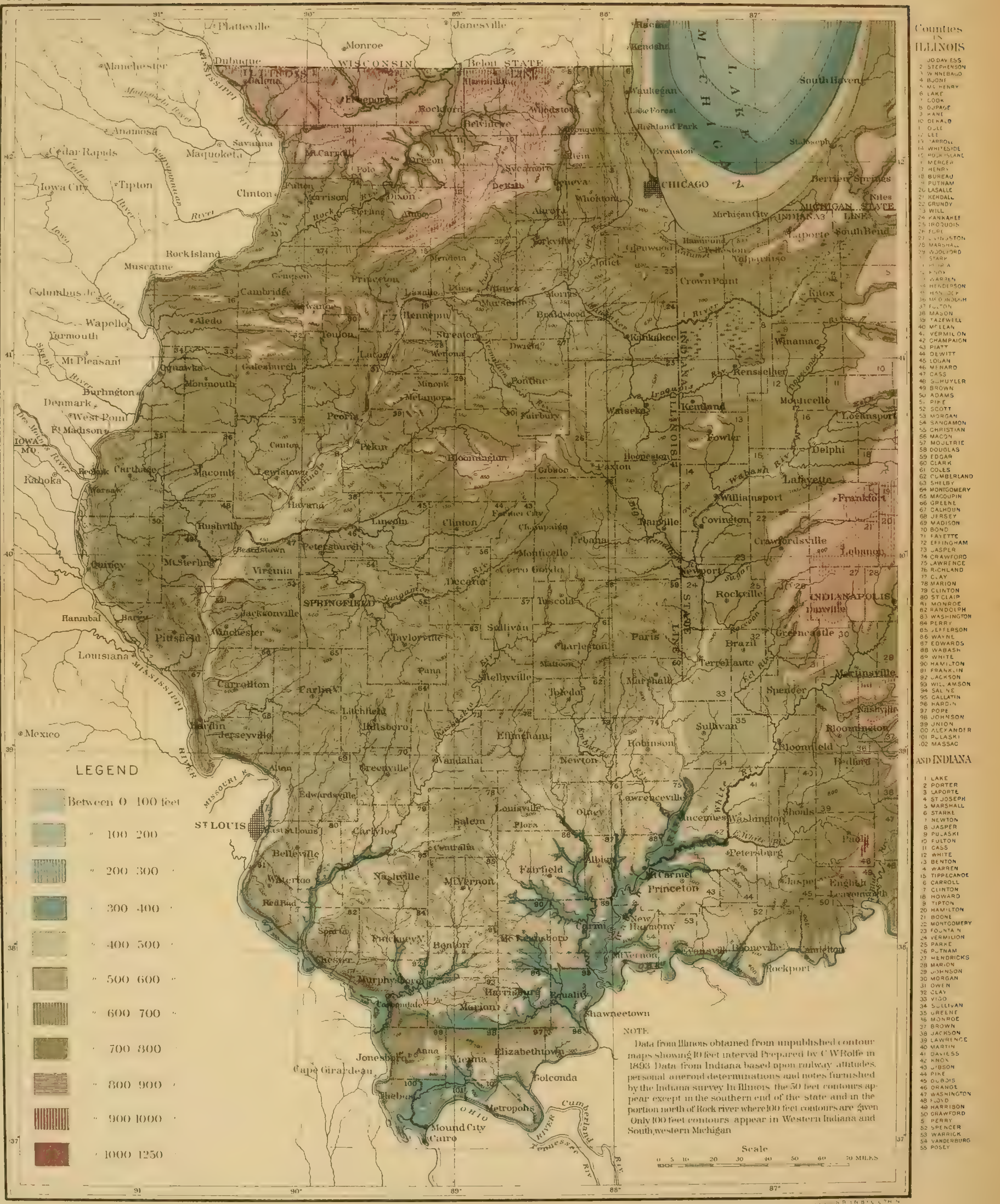
[1] The average elevation of the United States, by Henry Gannett: Thirteenth Ann. Rept. U. S. Geol. Survey, 1892, p. 289.

[2] See discussion by R. D. Irving: Geol. of Wisconsin, Vol. II, 1877, pp. 632–634. Also T. C. Chamberlin: Ann. Rept. Wisconsin Geol. Survey, 1878, pp. 23–32.

care in reducing to a minimum errors arising from barometric fluctuations. He has kindly allowed the writer to trace from his unpublished map sheets such contours as are represented on the accompanying map (Pl. III). In the hilly-driftless tracts in the northwest corner, and in the southern end of the State, the surface is so uneven that only 100-foot contours are introduced. But the altitude of the greater part of the State is represented by contours with 50-foot interval. For very small areas, covering but a fraction of a square mile, the contours must necessarily be omitted on a map of so small scale. A few such areas occur in the hilly districts in the northwestern and the southern portions of the State. In Pl. IV the areas between each 100-foot contour are shown in color, and the bottom of Lake Michigan is also represented.

In a general way the altitude decreases from north to south in the State of Illinois, there being four counties on the north border (Jo Daviess, Stephenson, Boone, and McHenry) in which points rise 1,000 feet above tide. Near the southern border of the Coal Measures basin the average altitude is below 500 feet. There is, however, south from the Coal Measures basin a prominent ridge which rises nearly to the altitude of the northern portion of the State, its crest reaching at one point an altitude of 1,047 feet (Rolfe). A reference to Pls. III and IV will make clear the altitudes and slopes of Illinois and also of the portions of southwestern Michigan and western Indiana embraced in this discussion. The highest point in Illinois (1,257 feet) is Charles Mound, on the Illinois-Wisconsin line, in the northwest county. The lowest points are near the junction of the Ohio and Mississippi, and fall slightly below 300 feet at low-water stages of the stream. At high-water stages none of Illinois is below 300 feet. It appears from the table below (p. 12) that only 125 square miles, or an area of less than four townships, rises above the 1,000-foot contour, and that only 10,747 square miles, or less than one-fifth of the State, falls below the 500-foot contour. About 20,000 square miles, or more than one-third of the State, stands at 600 to 700 feet above tide, or at about the average altitude of the State.

The thickness of the drift is so great in the northeastern fourth of Illinois as to convey a false idea of the altitude of the rock surface in that region. Were the drift coating entirely removed, the average elevation would probably be as low as the surface of Lake Michigan (580 feet above tide), and



MAP OF ILLINOIS AND NEIGHBORING DISTRICTS SHOWING AREAS BETWEEN 100 FOOT CONTOURS

BY FRANK LEVERETT

1898

possibly it would not exceed 500 feet above tide. This low altitude extends eastward some distance into Indiana. The low altitude of this district, as well as that of the Lake Michigan basin, as noted above, probably influenced the ice flow and invited its great southward extension in the State of Illinois.

The following table showing the range in altitude of the drift surface and of the rock floor in each county of Illinois serves to show not only the general range but also the variations within small districts. As the impression prevails widely that Illinois is a very level region, the table may be of service in dispelling this illusion. The impression of flatness arises from the general absence of abrupt reliefs. A comparison of the ranges in altitude in the several counties shows that 18 counties have a range of over 400 feet in their drift surface and that 22 show an equally great range in rock surface. In 55 counties, or more than half the number in the State, there is a range of less than 300 feet in the drift surface, while in 62 counties the known range in rock surface falls below 300 feet. In the remaining 29 counties the range in altitude of drift surface falls below 200 feet.

Table showing altitudes of drift surface and rock floor, with their range, in each county of Illinois. (*a*)

County.	Highest point.	Highest known rock surface.	Lowest point.	Lowest known rock surface.	Range in drift surface.	Range in rock surface.
Jo Daviess	1,257	1,257	575	453	(?)	804
Stephenson	1,170	1,170	735	(500)	435	(670)
Winnebago	990	975	680	(425)	310	(550)
Boone	1,040	1,000	720	(450)	320	(550)
McHenry	1,040	875	740	580	300	295
Lake	913	607	581	505	332	102
Cook	910	699	581	478	329	221
Dupage	812	680	581	581	231	99
Kane	975	760	614	579	361	181
Dekalb	950	813	649	542	301	271
Ogle	1,000	1,000	660	(400)	340	(600)
Lee	1,017	875	649	(400)	360	(475)
Carroll	1,020	1,000	568	435	452	565
Whiteside	890	850	564	435	326	415
Rock Island	840	675	530	(425)	310	(250)
Mercer	857	736	523	(385)	334	(351)
Henry	850	815	562	560	288	255
Bureau	987	800	431	330	556	470

a Altitudes of rock surface in parentheses have been inferred from known altitudes in bordering counties.

Table showing altitudes of drift surface and rock floor, etc.—Continued.

County.	Highest point.	Highest known rock surface.	Lowest point.	Lowest known rock surface.	Range in drift surface.	Range in rock surface.
Putnam	740	565	430	330	310	235
Lasalle	930	680	433	330	497	350
Kendall	760	640	540	509	220	131
Grundy	700	552	477	465	223	97
Will	820	700	485	485	335	215
Kankakee	750	690	550	538	200	152
Iroquois	780	615	650	260(?)	180	355(?)
Ford	840	561	650	350	190	211
Livingston	840	688	588	365	252	323
McLean	913	700	650	469 —	263	231 +
Tazewell	820	575	425	325	395	250
Woodford	830	621	429	(325)	401	(296)
Marshall	895	585	430	(325)	465	(260)
Stark	850	800	620	600	230	200
Peoria	835	780	425	341	410	439
Knox	850	800	536	536	314	264
Warren	810	750	(?)	450	(?)	300
Henderson	770	670	505	(375)	265	(295)
Hancock	765	685	468	(375)	297	(310)
McDonough	775	680	500	500	275	180
Fulton	750	740	422	(325)	328	(415)
Adams	750	735	452	(350)	398	(385)
Schuyler	750	645	417	(345)	333	300
Brown	807	710	414	(345)	393	(365)
Mason	650	371	420	(325)	230	(46)
Cass	690	550	415	345	275	205
Menard	650	600	445	(325)	205	(275)
Logan	744	550	520	379 —	224	171 +
Dewitt	800	541	585	359 —	215	182 +
Macon	760	556	550	400	210	156
Piatt	820	480	600	480	220	(?)
Champaign	830	676	610	440	220	236
Vermilion	790	650	480	436	310	214
Edgar	839	652	480	480	359	172
Clark	770	620	430	(355)	340	(265)
Cumberland	700	600	510	510 —	190	90 +
Coles	799	635	575	538 —	224	97 +
Douglas	725	481	610	481	115	(?)
Moultrie	750	490	560	490	190	(?)
Shelby	770	625	490	538 —	280	87 +
Christian	750	650	530	497	220	135
Sangamon	720	707	512	512	208	195

Table showing altitudes of drift surface and rock floor, etc.—Continued.

County.	Highest point.	Highest known rock surface.	Lowest point.	Lowest known rock surface.	Range in drift surface.	Range in rock surface.
Morgan	737	665	413	(345)	324	(320)
Scott	714	637	410	(345)	304	(292)
Pike	880	800	408	325 —	472	475 +
Calhoun	810	775	403	(300)—	(?)	(475)+
Jersey	830	800	391	(300)	439	(500)
Greene	(?)	616	404	(300)	(?)	(316)
Macoupin	740	672	500	440 —	240	232 +
Montgomery	750	662	530	527	220	135
Madison	650	600	381	284	269	316
Bond	675	600	450	351	225	249
Fayette	650	600?	435	405	215	195
Effingham	680	650	476	476 —	204	174 +
Jasper	660	600	410	395 —	250	205 +
Crawford	590	550	400	350	190	200
Lawrence	500	490	391	(345)	109	(145)
Richland	590	510	385	385 —	205	125 +
Clay	650	600	396	396 —	254	204 +
Marion	650	635	435	379	215	256
Clinton	570	500	378	375 —	192	125 +
St. Clair	758	735	375	284	383	451
Monroe	750	740	360	350 —	390	390 +
Randolph	712	675	340	340 —	372	335 +
Washington	580	580	378	375 —	202	205 +
Perry	575	575	385	380 —	190	195 +
Jefferson	620	600	415	415 —	205	185 +
Wayne	540	430	368	368 —	172	162 +
Edwards	560	560	370	344 —	190	216 +
Wabash	615	615	365	344 —	250	271 +
White	590	590	323	323 —	267	267 +
Hamilton	616	616	340	340 —	276	276 +
Franklin	550	500	380	375 —	170	125 +
Jackson	860	850	323	318 —	(?)	532 +
Williamson	750	750	370	370 —	(?)	380 +
Saline	864	864	350	345 —	(?)	519 +
Gallatin	810	810	304	240	(?)	570
Hardin	810	810	298	290 —	....	520 +
Pope	1,047	1,047	290	280 —	....	767 +
Massac	550	550	280	270 —	....	280 +
Johnson	800	800	335	330 —	....	470 +
Union	985	985	296	260 —	....	725 +
Alexander	619	619	279	270 —	....	349 +
Pulaski	489	489	279	270 —	....	219 +

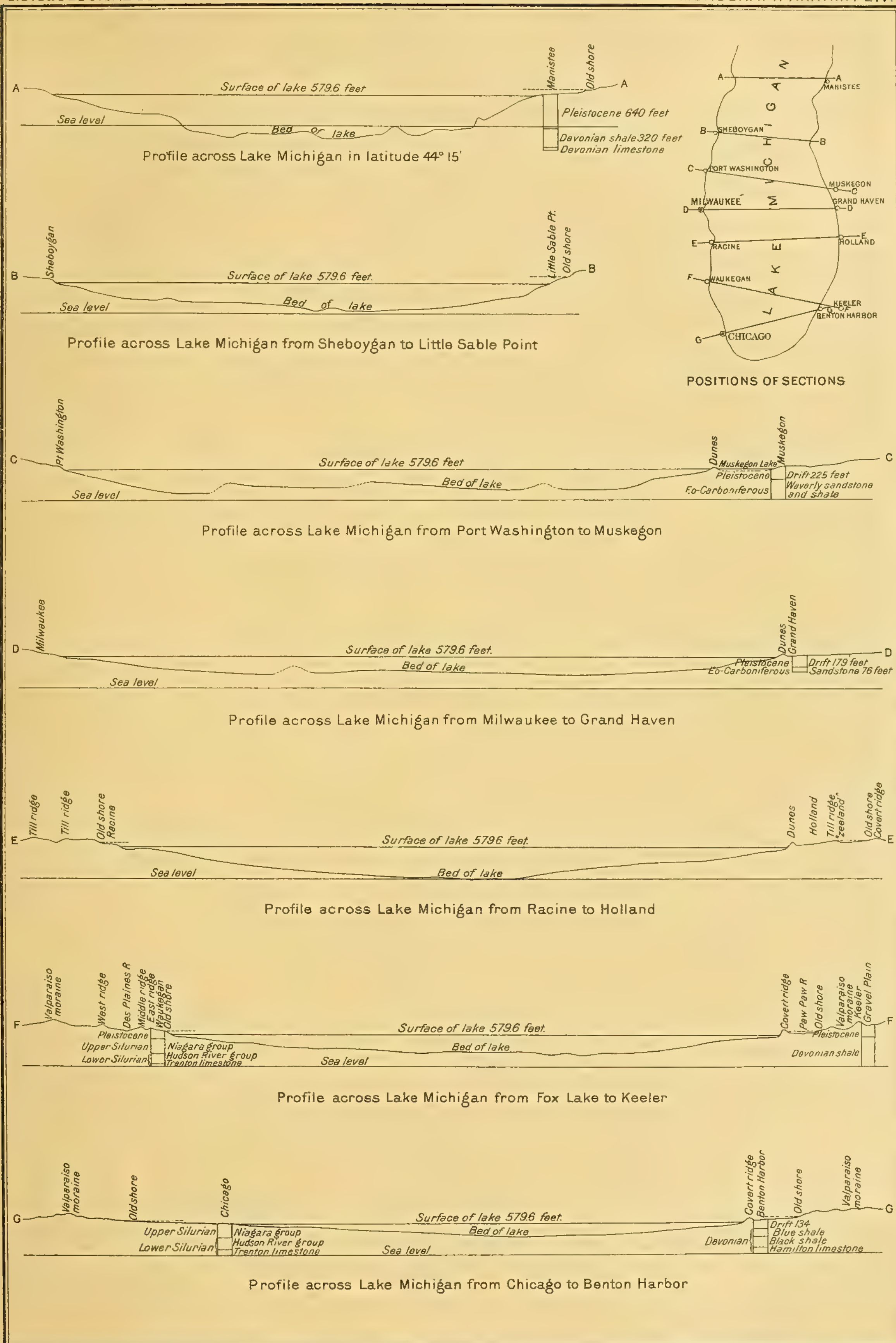
From Professor Rolfe's maps estimates have been made of the areas between each 100-foot contour in each county, and the results combined for the entire State. By these estimates the average altitude of the State is 633.55 feet, or but a few feet different from the estimate made by Mr. Gannett. The average thickness of drift in the State is estimated to be between 100 and 130 feet. (See discussion, Chapter XIII.) If the thickness of the drift be deducted, the average altitude of the rock surface in the State will be about 525 feet, or fully 50 feet below the surface of Lake Michigan. The following table gives the estimated areas between 100-foot contours for the entire State:

Estimated areas in Illinois between 100-foot contours.

	Square miles.
Above 1,200 feet	1
Between 1,100 and 1,200 feet	6
Between 1,000 and 1,100 feet	118
Between 900 and 1,000 feet	1,009
Between 800 and 900 feet	3,981
Between 700 and 800 feet	11,127
Between 600 and 700 feet	20,058
Between 500 and 600 feet	9,603
Between 400 and 500 feet	8,822
Between 300 and 400 feet	1,925
Area of Illinois	56,650

As noted above, the Illinois lobe extended into western Michigan and western Indiana, and also into southeastern Iowa. Contour maps of these districts have not yet been made, except in portions of Scott and Muscatine counties, Iowa, covered by the United States Geological Survey sheets. The numerous railway surveys have, however, established the altitude of so many points that a fair estimate of the altitude of these districts may be made. It is found that the drift surface has an average altitude slightly higher than that of Illinois, but it will scarcely exceed 650 feet above tide. The rock surface, on the other hand, appears to be a few feet lower than the average for Illinois. The inclusion of these districts, therefore, scarcely makes a measurable change in the average altitude of the region covered by the Illinois lobe. But if the Lake Michigan basin be included, it will materially lower the average altitude.

Profiles across the basin of Lake Michigan have been prepared from Lake Survey charts which bring out certain prominent features of the southern end of the Lake Michigan basin as it now appears with its coating



JULIUS BIEN & CO. LITH. N.Y.

PROFILES ACROSS THE BED OF LAKE MICHIGAN

(Based on soundings given in the United States Lake Survey Charts)

BY

FRANK LEVERETT

1898.

of drift (see Pl. V). The first two profiles show a gradual slope from the west side to points beyond the middle of the lake, followed by a somewhat abrupt rise to the east shore. The amount of drift on the east shore is somewhat greater than on the west, the rock floor at St. Joseph being but 456 feet above tide, or 124 feet below the lake, while on the west shore it rises in many places 20 or 30 feet above the lake level and generally is not far below it. The next profile leading eastward from Racine passes across the deepest part of the basin in the southern end of Lake Michigan, and shows no essential difference on opposite sides of the lake in the slope of the lake bottom. The slopes and bottom are very smooth compared with those shown in profiles farther north. The profile leading from Milwaukee to Grand Haven shows a much shallower part of the basin than that east from Racine, the altitude being nowhere below 200 feet above tide, while opposite Racine it reaches sea level. This line between Milwaukee and Grand Haven seems to mark nearly the summit of a ridge between two basins, both of which, together with the dividing ridge, are covered by the lake. In the profile a few miles to the north, leading from Port Washington, Wisconsin, to Muskegon, Michigan, the lake bottom is shown to be singularly irregular. The appearance presented is that of a series of escarpments facing westward, similar to the escarpment of Lockport (commonly known as Niagara) limestone a short distance west from Lake Michigan, but it is not entirely certain that they are rock escarpments. Were the drift to be removed from the eastern border of the basin the profile would be quite different. A well at Muskegon, reported by the Michigan Geological Survey, has 235 feet of drift, which brings the rock floor down to an altitude but 360 feet above tide, or only a few feet above the crests of the ridges in the midst of the lake. The dotted line at the right of the profile indicates the depth of the drift at that point. The profiles north from this line show irregularities of lake bottom which give it the appearance of being channeled longitudinally. Whether these irregularities are due to drift accumulations or to rock ridges is not manifest from an inspection of the lake charts. The remarkable thickness of drift at Manistee (640 feet) is worthy of note, and indicates that the abrupt border of the lake there is of drift.

Evidence that the present smooth bottom of the Lake Michigan basin in its southern end is due to the planeness of the drift surface instead of the

smoothness of the rock floor is found in borings near Michigan City. Three borings in a line leading from Michigan City westward 2 miles show a ridge capped by Devonian shale at the middle boring, which stands 70 or 80 feet above a rock floor of limestone at the other wells.

Taking the basin as a whole, interesting contrasts appear. The remarkable depth and the smoothness of the south-central portion of the basin shown in the profile east from Racine seem to favor the view that glacial erosion was there an agency of much consequence. The preservation of the shale at Michigan City (a few miles to the south) and the apparent preservation of old escarpments in the midst of the basin a few miles to the north, both being in more prominent and apparently better exposed situations for effective erosion than the deep part between them, seem to show comparatively little erosion. The evidence therefore as to the amount of glacial erosion is somewhat confusing, and it will be found difficult to eliminate this factor if an attempt to restore the preglacial features of the basin be made.

The reliefs of the region covered by the Illinois lobe are seldom of a bold or conspicuous type. On the contrary, they are so gradual as to give the impression that they are less than the instrumental determinations indicate. There are, however, a few ridges with rock nuclei which are of sufficient prominence to merit notice.

The most prominent ridge of the region is found in the southern portion of Illinois, at the southern border of the glaciated district. This ridge crosses the State in a direction nearly due east and west from the bend in the Ohio River just south of the mouth of the Wabash to the Mississippi River near Grand Tower. Its crest ranges from about 700 to 1,047 feet above tide (Rolfe), and its breadth ranges from 5 or 6 to 10 or 12 miles. It stands 300 to 600 feet above the lowlands on the north, their altitude being but 400 to 550 feet above tide, and an even greater amount above the lowest parts of the district on the south. This ridge seems to have limited the extension of the ice sheet, for the drift was carried well up toward the crest on the north slope, but no decisive evidence has been found that the crest was overridden.

From the western end of the ridge just noted, northwestward along the Mississippi to St. Louis, an elevated limestone belt separates the river valley from the Coal Measures district to the northeast. This belt is but

5 to 10 miles wide and stands 650 to 750 feet above tide, while the Coal Measures district bordering it stands only 450 to 600 feet above tide. It is interrupted by gaps 2 miles or less in width where the Big Muddy and the Kaskaskia pass through it to the Mississippi; otherwise it forms a continuous belt. Its altitudes are no greater than those of the district across the river in Missouri. On the contrary, there is a rise in that direction to the Iron Mountain district of southeastern Missouri. It seems remarkable that the Mississippi should have taken a course across this limestone belt, and as yet no satisfactory explanation for this feature has been found. The stream is apparently in a preglacial valley. Its course seems, therefore, to be independent of glaciation. This belt, like the ridge of southern Illinois, seems to mark the limit of the ice sheet. Drift in small amount occurs over most of its surface, but, so far as known to the writer, does not extend beyond the Mississippi. Near St. Louis, however, where the limestone border passes to the west side of the river, drift is found in small amount.

Passing up the Mississippi to the mouth of the Illinois, a narrow axis of upheaval is found, trending nearly east and west, along which the altitude is somewhat greater than on bordering districts. Just east of the mouth of the Illinois there are a few points where the rock surface rises to about 800 feet, while on the plain north of this ridge the rock scarcely exceeds 650 feet. West from the Illinois the altitude is not markedly greater at this axis than to the northward, there being a narrow limestone ridge between the Mississippi and the Illinois through the entire length of Calhoun County, whose crest is generally 700 to 750 feet above tide. The altitude of the ridge west of the Illinois is fully 100 feet greater than that of the bluffs immediately east of that stream. These elevated limestone ridges, and similar ridges on the Missouri side of the Mississippi, near the town of Louisiana and southward, carry very little drift and, as noted some years since by Salisbury, may not have been completely covered by the ice sheet.[1]

Of the three belts just described two have been sculptured very deeply by surface erosion, viz, the ridge crossing southern Illinois and the ridge near the mouth of the Illinois. The remaining belt (along the Mississippi below St. Louis) is less deeply sculptured because in much of its extent underground drainage through sink holes and caves has been established.

[1] Proc. Am. Assoc. Adv. Sci., Vol. XL, 1891, pp. 251–253.

There is not even a well-developed system of ravines and tributaries on its surface, but ravines partially developed often discharge their waters into sink holes and have no surface indications of connection with other lines of drainage.

In the northwestern part of Illinois a few conspicuous outlying mounds of Lockport (Niagara) limestone appear. Some of these are situated in the drift-covered region and others in the Driftless Area. They rise 75 to 300 feet above border districts. The majority of these mounds rise above the 1,100-foot contour, and one of them, Charles Mound, as noted above, forms the highest point in the State (1,257 feet). They vary in size from a fraction of a mile to several square miles. In the latter case a chain of mounds occurs, rather than a single mound or ridge. These mounds lie but a few miles north and east of continuous Niagara formations and were apparently once joined with them, their separation, as long since stated by Worthen, being due to denudation.[1] The greater part of the district among these mounds has been denuded of the Hudson River or Maquoketa shales as well as of the Lockport limestone, thus exposing the Galena limestone.

East from the district just discussed is the broad drainage basin of Rock River, which has no conspicuous ridges or remnants of higher strata capping its present surface formations, though the latter are thoroughly sculptured by drainage lines.

Between the Rock River drainage line and Lake Michigan there is a somewhat elevated belt of limestone, which extends curvingly in a direction east of south into western Indiana. It is generally so heavily covered with drift that its lesser features can only be conjectured. Borings indicate that variations of 100 feet or more in altitude occur within a distance of a few rods. It was in all probability thoroughly sculptured by drainage lines. The rock surface has its greatest altitude at the north, being 400 feet above Lake Michigan at the Illinois-Wisconsin line, while in the vicinity of the Indiana line it rises only 100 to 200 feet above the lake. The Fox, Des Plaines, and Kankakee rivers now cross this limestone belt from the low belt bordering Lake Michigan into the old Rock and Illinois drainage basin, thus extending the latter at the expense of the former.

In southern Indiana there is a comparatively elevated region along the east border of the Coal Measures formed largely by the Conglomerate

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[1] Geology of Illinois, Vol. I, 1866, p. 4.

sandstone. This was partially covered by the ice sheet. The highest points within the glaciated portion seldom, if ever, exceed 900 feet, but with this altitude they stand 200 to 300 feet or more above the general level of the rock surface near the Wabash, only a few miles to the west. This sandstone forms the western border of a broad tract of elevated land, which is greatly eroded and hence is called the "hill country" of Indiana. Its northern portion has had the irregularities greatly softened by glaciation. The southern portion was less heavily glaciated and is nearly as rough as the unglaciated tracts.

The district occupied by the Coal Measures, both in Illinois and in Indiana, has a general altitude somewhat lower than that of the bordering limestone or sandstone. Prior to the ice invasion its surface had been greatly eroded, leaving narrow divides at the water partings more or less dissected into low hills, while the streams occupied broad shallow troughs. These features are only partially concealed in southern Illinois and southwestern Indiana. As already noted, streams which flow from the Coal Measures into the lower Carboniferous limestone show a marked reduction in the size of the channel upon entering the limestone. This is true not only of small rivers like the Kaskaskia, but also of large streams. The valley of the Illinois is reduced in breadth from 8 or 10 miles to scarcely 3 miles on entering the limestone on the border of Pike and Greene counties. The preglacial Mississippi, now partly filled with drift, is narrowed in breadth from 10 or 12 miles, or possibly 15 miles, in the Coal Measures of Louisa County, Iowa, and Mercer County, Illinois, to only 5 or 6 miles on entering the limestone a few miles above Burlington, Iowa. Where streams do not enter the limestone a gradual widening occurs toward the mouth. The Wabash occupies a preglacial valley in which the breadth increases gradually southward and reaches 10 or 15 miles in the vicinity of its mouth. Below Terre Haute the breadth varies from 5 or 6 miles to 15 miles or more, and in places the bluffs are very poorly defined, owing to the fact that the strata of the bordering districts have broken down nearly as rapidly as the valley was deepened. The several tributaries of the Wabash in southern Illinois—the Embarras, Bon Pas, and Little Wabash—have broad trough-like valleys 2 to 4 miles in width in their lower courses, and their bluffs are often vaguely defined, like those of the main stream.

Occasional basin-like expansions of river valleys appear outside the Coal Measures. One formed in the Hudson River or Maquoketa shales and underlying formations along the Pecatonica River near Freeport has a breadth of about 4 miles where widest, though usually it is but 2 or 3 miles. This basin has been discussed recently by Mr. Oscar Hershey as a peneplain,[1] but to the writer it appears too immature to be thus classed. A similar basin borders Elkhorn Creek in Carroll and Whiteside counties. The Mississippi Valley also has an expansion where it crosses these shales on the borders of Carroll County, Illinois, and Jackson County, Iowa, being fully twice as wide as it is where cut in the Galena or in the Lockport (Niagara) limestone. These contrasts in width are well shown in the Clinton, Savannah, and other topographic sheets covering this part of the Mississippi Valley. The Clinton sheet appears as Pl. XVIII of this report.

Most of the streams in this region have courses independent of the preglacial drainage lines. It is only in the western half and southern third of Illinois and in southwestern Indiana, where the drift is comparatively thin, that the course of preglacial drainage can be confidently indicated. Even here the larger valleys only are traceable, for the valleys of the smaller streams have usually been completely filled, and deep borings are too few to supply data to map out their position and connections. The effect of glaciation on the drainage will appear in the progress of the discussion.

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[1] Am. Geologist, August, 1896.

CHAPTER III.

OUTLINE OF TIME RELATIONS OR GLACIAL SUCCESSION.

In the progress of the studies of glacial deposits the complexity of the glacial history has been gradually unfolded. After the abandonment of the iceberg hypothesis, the early students approached the study with the hypothesis of a single and practically continuous period of deposition, in which the ice sheet at one time covered the entire glaciated area. This period was supposed to have terminated with a single high stage of water, attending the melting of the ice, which was termed the Champlain epoch. It soon became apparent that this simple hypothesis could not be made to cover the complicated glacial history. Evidences of a succession of recessions and advances of the ice sheet have appeared, and a sharp controversy has arisen concerning the importance of these oscillations, it being held by some students that they are of minor importance and mark short or partial retreats and advances in a single epoch of glaciation, while others have contended for the necessity of recognizing two or more ice invasions between which were very extensive and prolonged deglaciation intervals. The studies upon which the present report is based have developed evidence which, it is thought, has an important bearing upon the question in dispute. The writer, like others who have studied this region, has been greatly impressed with the evidence of prolonged intervals of deglaciation, and an attempt will be made to set forth the nature of this evidence.

The several sheets of glacial drift which this and neighboring regions contain have received geographic names, as have also some of the interglacial beds. Names of this class were proposed by Chamberlin as a substitute for time phrases which had arisen and which were of controverted application.[1] They have already come into wide use in glacial literature, and are employed by students who hold the divisions to be of minor importance as well as by those who consider them of great importance. The

[1] See Geikie's Great Ice Age, third edition, 1894, pp. 754–774. Also Jour. Geol., Vol. III, pp. 270–277, and Vol. IV, pp. 872–876.

divisions to which Chamberlin has applied names appear to have the rank of the main divisions of the Glacial period, whatever that rank may prove to be. Other names are necessary to denote the subdivisions. In the present report several names are thus introduced to designate the moraines associated with the older as well as the newer sheets of drift. The name selected is usually that of a town located on the moraine. In most cases the names have come into use in the office and in correspondence with other glacialists, as a convenient form of reference. The selection thus made seems suitable for general use.

In the outline given below it is aimed to cover the events between the deposition of the oldest-recognized drift sheet in North America and the final recession of the ice sheet or sheets into the region north of the Great Lakes. The main divisions appear to be much longer than the secondary ones. It is concerning the former that the value of time intervals is a matter of dispute. The secondary divisions of the drift deposit are not thought by any students to be marked by intervals sufficiently prolonged to merit the application of the term epoch. It is probable, however, as shown farther on, that some oscillation of the ice front occurred, so that the moraines on which these subdivisions are based do not mark simply halts in the recession of the ice, but rather readvances after recessions of minor consequence. To avoid the use of the controverted term *epoch*, it is thought best to employ the term *stage*, which gives a less definite time value.

Outline of the drift sheets and intervals.

Stage 1. Oldest recognized drift sheet—the Albertan of Dawson, including, also, the sub-Aftonian of Chamberlin.
Stage 2. First interval of deglaciation—Aftonian of Chamberlin.
Stage 3. Kansan drift sheet of the Iowa geologists.
Stage 4. Second interval of recession or deglaciation—Yarmouth of Leverett.
Stage 5. Illinoian drift sheet.
Stage 6. Third interval of recession or deglaciation—Sangamon of Leverett.
Stage 7. Iowan drift sheet and main loess deposit.
Stage 8. Fourth interval of recession or deglaciation—Peorian of Leverett, possibly equivalent to the Toronto Formation of Chamberlin.
Stage 9. Early Wisconsin drift sheets.

- Substage 1. Shelbyville morainic system
  - Shelbyville moraine.
  - Cerro Gordo moraine.
- Substage 2. Champaign morainic system
  - Outer ridge.
  - Middle ridge.
  - Inner ridge.
- Substage 3. Bloomington morainic system
  - Bloomington or outer main ridge.
  - Normal or inner main ridge.
  - Subordinate ridges.
- Substage 4. Marseilles morainic system
  - Marseilles moraine.
  - Possibly Minooka till ridge.

Stage 10. Fifth interval of recession, unnamed; shown by shifting of ice lobes.
Stage 11. Late Wisconsin drift sheets.
 Substage 1. Great bowlder belts and accompanying moraines, including, perhaps, the Minooka till ridge.
 Substage 2. Valparaiso morainic system.
 Substage 3. Lake border morainic system.
Stage 12. Lake Chicago submergence.
Stage 13. Emergence of plain covered by Lake Chicago.
Stage 14. Partial resubmergence of plain covered by Lake Chicago.
Stage 15. The present stage of Lake Michigan.

The outline just presented differs from the one last presented by Chamberlin[1] in the separation of the Wisconsin drift series and lake history into the several substages, and the introduction of names for three interglacial stages. Except for the introduction of names for the interglacial stages, it is essentially the same as an outline presented by the writer in a recent bulletin of the Chicago Academy of Sciences.[2]

Mr. J. B. Tyrrell of the Canadian Geological Survey, who has studied widely in western Canada, favors the separation of the Albertan and sub-Aftonian stages. In a letter to the writer dated July 9, 1897, which discusses the outline given in the bulletin just referred to, he makes the following statement:

The Albertan drift sheet of Dawson is older than any till of the Keewatin glacier seen in the plains of northwestern Canada, while the Upper and Lower Bowlder Clay of our Reports seem to correspond closely with your Kansan and sub-Aftonian. I should, therefore, completely separate the Albertan and sub-Aftonian.

In the present stage of investigation the correlation of the Upper and Lower Bowlder Clays of the Canadian Reports with the Kansan and sub-Aftonian of southern Iowa is not worked out satisfactorily. The full extent of either the Kansan or sub-Aftonian in districts lying between Iowa and the Canadian boundary is not determined. It therefore may be hazardous to venture definite correlation, though the balance of probabilities, as suggested by Tyrrell, seems to favor this correlation and the transference of the Albertan to an earlier stage.

The complexity of the glacial history is still further increased by the occurrence of more than one gathering ground or center of dispersion of the ice. The explorations of the Canadian Survey have shown that there

[1] Jour. Geol., Oct.–Nov., 1896, Vol. IV, No. 7, pp. 872–876.

[2] Pleistocene features and deposits of the Chicago area, by Frank Leverett: Bull. Chicago Acad. Sci. No. 2; issued May, 1897.

were three main centers of dispersion aside from Greenland. The Cordilleran region of western Canada contained one ice field from which there was dispersion in all directions. The province of Keewatin, west of Hudson Bay, contained another ice field which spread in all directions and reached the glacial boundary in Missouri and States to the southwest. The third ice field occupied the highlands east and south of Hudson Bay. It spread to the borders of the Atlantic on the north and east, and to the borders of the Mississippi and Ohio on the southwest and south. The two ice fields bordering Hudson Bay probably for a time coalesced to form the Laurentide ice sheet of Dawson.[1] But they were apparently distinct and independent centers for a considerable part of the Glacial period. The names Keewatin and Labrador seem appropriate for these independent centers of glaciation, the former being a name proposed by Mr. Tyrrell, and the latter one which has been used by several glacialists in correspondence and to some extent in print. The name Cordilleran has been applied by Dawson to the ice field in western Canada. There appears to have been less complete coalescence of this ice field with the Keewatin than that between the Keewatin and Labrador ice fields.

The Cordilleran ice field, as shown by Dawson, occupied a portion of the Rocky Mountains and extended eastward into the province of Alberta, in the early stage of glaciation, when the Albertan drift sheet was deposited.[2] This advance long preceded the maximum westward extension of the Keewatin ice field. Whether the sub-Aftonian or any other deposits of the Keewatin ice sheet are as old as the Albertan, as noted above, is not satisfactorily determined.

The Keewatin ice sheet apparently reached its farthest limits on the borders of the Mississippi at the Kansan stage of glaciation. The recognition of the sub-Aftonian—an older deposit than the Kansan—in southern Iowa is based upon the exposures of this drift sheet under a somewhat fresher sheet of Kansan drift. The extent of the sub-Aftonian toward the south and west compared with that of the Kansan is not yet determined. In a paper presented at the twelfth annual meeting of the Iowa Academy of Sciences, in December, 1897, Dr. H. Foster Bain, of the Iowa Geological Survey, gave a careful review of the features of the sub-Aftonian and

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[1] See Am. Geologist, Vol. VI, 1890, pp. 153–161.

[2] Bull. Geol. Soc. America, Vol. VII, pp. 31–66; issued November, 1895.

descriptions of the weathered zone between this till sheet and the overlying Kansan. The extent of weathering appears to him scarcely sufficient to warrant a separation into a distinct glacial stage. He, however, suggested that the sub-Aftonian sheet may have been formed during one of the hypothetical minor advances of the ice sheet preceding its maximum extension.[1]

The portion of the Labradorian ice field to which the name Illinois Lobe is applied, reached its farthest limits on much, if not all, of its border at the Illinoian stage of glaciation. The Illinoian drift sheet, as indicated in detail farther on, passed some distance into territory which had been occupied by the southern extension of the Keewatin ice sheet at the Kansan stage. Since the Illinois ice lobe reached its farthest limits on much of its border at the Illinoian stage of glaciation, any earlier deposit made by this ice lobe must be largely concealed by the deposits of this stage. Attention is called below to deposits in Illinois which may prove to be sufficiently older than the Illinoian to be referable to a distinct stage, though the evidence as yet is rather fragmentary. Concerning this matter Professor Chamberlin has suggested[2] that the two great ice fields may have alternated in their invasions in such manner that the sub-Aftonian preceded the sub-Illinoian and the latter preceded the Kansan, much as the Kansan is known to have preceded the Illinoian. There is, however, as yet no decisive evidence of such a relationship. Possibly the sub-Illinoian will prove to be of about the same age as the Kansan. With these preliminary statements we pass at once to the discussion of the Illinoian stage of glaciation.

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[1] Proc. Iowa Acad. Sci., Vol. V, 1898, pp. 86–101.

[2] Communicated to the writer.

CHAPTER IV.

THE ILLINOIAN DRIFT SHEET AND ITS RELATIONS.

GENERAL STATEMENT.

Relation to outlying and underlying drift.—The first recognition and separation of the Illinoian drift sheet from an older sheet of drift which underlies it on the borders of the Mississippi was made by the writer in southeastern Iowa in the spring of 1894. The occurrence of a bowlder of red jaspery conglomerate in Lee County, Iowa, had been noted some ten years earlier, but its significance was not recognized at that time. It is now found that bowlders of this class are not rare, and that they are in all probability derived from the ledges north of Georgian Bay. If so, they are an indication that the southwestward movement of the ice from that region extended somewhat beyond the Mississippi River. The studies in 1894 developed other evidence that the invasion which brought in these bowlders from the northeast reached beyond the Mississippi, and that it occurred at a much later date than the general glaciation of southern Iowa and northern Missouri. The western limits of this ice invasion are plainly indicated by a marginal ridge. The evidence of a long interval is found in the greater erosion of the drift sheets outside the limits of the Illinoian, and in the prevalence of a soil horizon and weathered zone beneath the Illinoian sheet where it overlaps the earlier one. This interval appears to be of sufficient importance to be termed an interglacial stage and to justify the reference of the two sheets to distinct stages of glaciation. The intervening stage of deglaciation has recently been named the Yarmouth interglacial stage,[1] and is discussed farther on.

Relation to the Iowan drift sheet.—The question arises whether the Illinoian sheet should be classed with the Iowan sheet, which, as shown by McGee in the

[1] In a paper presented by the writer at the twelfth annual meeting of the Iowa Academy of Sciences, December, 1897: Proc. Iowa Acad. Sci., Vol. V, 1898, pp. 81–86; also Jour. Geol., Vol. VI, 1898, pp. 238–243.

GLACIAL MAP OF THE ILLINOIS ICE LOBE

BY FRANK LEVERETT

1898

Eleventh Annual Report of this Survey and in earlier papers, is separated from the underlying drift of eastern Iowa by a distinct soil horizon. It is found that a notable interval occurs between the deposition of the Illinoian sheet of drift and the deposition of the main sheet of loess of the Mississippi Basin, an interval indicated by erosion, weathering, and the formation of a soil horizon. But this sheet of loess seems to be intimately connected with the Iowan drift sheet, as shown by McGee, a relation which subsequent studies by several independent investigators fully confirms. It appears, therefore, that the Illinoian drift sheet is separated by a notable interval from the Iowan sheet as well as from the underlying sheets. Furthermore, a till sheet referred to the Iowan stage is present in northern Illinois which falls far short of reaching the limits of the Illinoian till sheet. Like the Iowan sheet of eastern Iowa, it is found to be contemporaneous with the main loess deposition. The interval between the Illinoian till sheet and the Iowan loess and till has recently been named the Sangamon;[1] it is discussed in some detail below. A deposit termed gumbo, which lies between the Illinoian till and the Iowan loess, is also described.

Culmination of the Illinois lobe at the Illinoian stage.—At the time of the deposition of the Illinoian drift sheet the southwestward movement from Labrador and the heights south of Hudson Bay appears to have reached a limit in western and southern Illinois beyond any earlier invasion. It is not as yet certain, though it is quite probable, that the Illinoian sheet extends beyond all older sheets in northwestern Illinois and southern Wisconsin. In the absence of positive evidence to the contrary the present paper discusses the western and southern limits of the drift of the Illinois lobe as a single line, occupied at the Illinoian stage throughout its entire length by the ice lobe. Its extent may be seen by reference to Pl. VI.

GENERAL ASPECTS OF THE ILLINOIAN DRIFT SHEET.

Extent of its exposures.—The Illinoian sheet is extensively exposed to view outside the Iowan and Wisconsin sheets in Illinois and southwestern Indiana. In western and southern Illinois and in southwestern Indiana it constitutes the surface sheet (aside from a thin loess coating) over the entire interval between the glacial boundary and the outer moraine of the Wisconsin series.

[1] In a paper presented by the writer at the twelfth annual meeting of the Iowa Academy of Sciences: Proc. Iowa Acad. Sci., Vol. V, 1898, pp. 71–80; also Jour. Geol., Vol. VI, 1898, pp. 171–181.

The greatest width of this area is about 125 miles, and the width nowhere in western or southern Illinois falls much below 75 miles. In southwestern Indiana it occupies a triangular-shaped area, broad at the west and narrow at the east, for the glacial boundary passes northward nearly to the edge of the Wisconsin drift in the south-central portion of that State.

In the portion of Illinois north from the latitude of Rock Island the Iowan drift occupies a large part of the interval between the glacial boundary and the outer moraine of the Wisconsin series. A drift, tentatively referred to the Illinoian, forms the surface sheet in that region in Stephenson County and parts of Winnebago, Ogle, Whiteside, Carroll, and Jo Daviess counties. A small area of this earlier drift in southwestern Wisconsin is exposed outside the limits of the Iowan, but the exact boundaries of the latter have not been determined.

If the loess capping be disregarded, nearly two-thirds of the glaciated portion of Illinois has the Illinoian drift as a surface sheet. The remainder of the State is mainly occupied by the Wisconsin drift sheet, the Iowan being exposed only in parts of a few counties.

Topographic expression.—The greater part of the Illinoian drift has a plane surface, destitute of the swells and ridges which usually occupy the Wisconsin till sheet. There are, however, a few belts of sharply ridged drift found within its area, and the border is ridged throughout much of southeastern Iowa and western Illinois. The most conspicuous ridging is found in a strip about 20 miles wide leading southwestward through the Kaskaskia Basin from the border of the Wisconsin drift in Shelby County across southeastern Christian, eastern and southern Montgomery, western Fayette, Bond, Clinton, southeastern Madison, eastern St. Clair, and eastern Randolph counties. This strip embraces a series of nearly parallel ridges, which are discussed in some detail farther on as the ridged drift of the Kaskaskia Basin.

Another ridged belt is found in eastern Sangamon and southwestern Logan counties, and this is discussed below as the Buffalo Hart moraine, the village of Buffalo Hart being situated on it. A less conspicuous belt of ridged drift traverses southern and western Fulton County, touching eastern McDonough County near Bushnell, and apparently having its continuance into Knox and Peoria counties in a chain of mounds and short ridges. It has far less prominence than the two belts just mentioned, its relief being but

15 to 30 feet above the bordering plains, and the breadth of the main ridge one-half mile, more or less.

In the northwestern part of Illinois, in Stephenson, Ogle, and Carroll counties, there are gravelly ridges, some of which are of esker type, and are discussed in detail below.

Aside from the ridged belts just mentioned, there have been found only occasional knolls, either isolated or in small clusters, and these seldom rise 50 feet above the bordering plains. The knolls are more abundant in western Illinois than in southeastern Illinois and southwestern Indiana. In the latter districts entire counties have been traversed without the discovery of a knoll so much as 10 feet in height.

Thickness of the drift.—The well records obtained in the region occupied by the Illinoian drift indicate that the average distance to rock on the preglacial or original uplands is not far from 50 feet. In this 50 feet is included the loess, which is several feet in depth, and possibly also pre-Illinoian drift. Along original valleys the thickness is 100 to 200 feet or more. There are extensive areas in the northwestern counties of Illinois and in the counties bordering the Wabash River, both in Illinois and in Indiana, where the ridges carry scarcely any drift, while neighboring valleys may be filled to a depth of 100 feet or more. In western and south-central Illinois the ridges usually carry 30 to 50 feet of drift, the general amount of drift being greater than in northwestern Illinois or southeastern Illinois and southwestern Indiana. Throughout the area occupied by the Illinoian drift the main preglacial valleys are usually but partially concealed, though the small valleys and tributaries are often filled so completely that their position is revealed only by borings. In this respect the Illinoian drift is in striking contrast with the Wisconsin, for where that sheet is present the main valleys are as completely concealed as the lesser ones.

Records of a large number of wells which have been sunk in the Illinoian drift area are presented in the portion of this report dealing with the wells (Chapter XIV).

Structure of the drift.—Throughout the area occupied by the Illinoian drift till predominates, there being but a small amount of sand or gravel except in deeply filled valleys. The ridges above mentioned are usually composed of till, though pockets or thin beds of sand or gravel have been discovered in some of them. Upon passing toward the glacial boundary

the drift becomes more variable in its constitution than at points remote from the boundary. This variableness is set forth in the detailed discussion of the drift border below.

The till which forms this Illinoian sheet is usually of a yellowish-brown color to a depth of 15 feet or more, beneath which it assumes a gray or blue-gray color. In many places there is a transition from the brown to the gray, in which gray streaks remain in the brown till, or cracks stained a brown color extend down some distance into the gray till. In such places it is probable that the brown is simply an altered gray till, the oxidation of the iron having produced the change in color. In places a thin bed of sand or gravel occurs at the junction of the brown and gray till, which gives them the appearance of being originally distinct. But it is not certain that the brown till in such places was not originally gray in color. The points at which there is a transition from till of one color to that of the other are so numerous that it seems highly probable that the brown till is generally but an altered phase of the gray. At least nothing decisive has been discovered to indicate that the brown and gray tills are referable to distinct invasions or to different modes of deposition by the ice.

In portions of central Illinois, especially in the Sangamon and Kaskaskia and Embarras drainage basins, the well diggers and drillers report a marked change in the texture of the drift in passing from the brown to the gray tills. The gray till is said to be much harder to penetrate than the brown. Where wells are dug, they may be spaded without difficulty through the brown till, while in the gray till a pick is usually required to remove the material. This difference may be due to the effect of ground water or to some secondary change in the brown till which does not affect the underlying gray till, a change which is coextensive with the change in color. It may, however, prove to be an original difference and may be of significance in determining the glacial history. Possibly the gray till in these districts is sufficiently older than the overlying brown till, or sufficiently distinct from it in deposition, to be referred to a separate stage and considered pre-Illinoian. But few exposures of this hard till were found, and in these no sign of a distinct interval between the brown and the gray tills was recognized. The available evidence is, therefore, of an inconclusive nature.

Gumbo (?).—The Illinoian till sheet, and also portions of the Kansan till sheet in southeastern Iowa and northern Missouri, are extensively covered

with a gummy or very adhesive clay, often several feet in depth. This clay is found at frequent intervals throughout the entire area in which the Illinoian sheet is exposed to view outside the limits of later till sheets, and has also been found under the later till sheets at some distance back from their margin in the central portion of Illinois. It occurs as far west as the writer has made examinations in Iowa, a distance of 50 miles or more beyond the limits of the Illinoian till sheet, and is known to be present over extensive areas in northern Missouri. Its extent and importance seem to have been unrecognized prior to the present survey. It is not such a continuous deposit as the overlying loess, there being many places where the loess rests directly upon typical till. It is most conspicuous in the vicinity of the Mississippi Valley and in the southern portion of Illinois as far south as the glacial boundary. The region in which it occurs ranges in elevation from 400 feet up to fully 800 feet above tide. Possibly much higher elevations are attained by it in passing westward from the Mississippi. Like the loess, it seems to be independent of contour lines in its distribution.

The color of this clay varies from ash or light gray to nearly black. The black portions are heavily charged with humus and in places present the appearance of a swamp muck. It is in this clay that the black soil so often seen at the base of the loess is usually developed. Where the loess rests directly upon till the soil formed beneath it is usually of a reddish-brown color.

This gummy clay contains a few small pebbles. They seldom exceed a half inch in diameter and are far less numerous than in the typical till. It often bears a striking resemblance to the "gumbo" of the Illinois and Mississippi River flood plains, which is deposited by flooded streams in the portions of the flood plains where there is but little current. It, however, contains more and larger pebbles than the gumbo of these flood plains.

The origin of this deposit, and its time relations compared with the overlying loess and the underlying till, are questions of prime importance, but as yet no satisfactory conclusions have been reached. There is much in the appearance of the deposit to support the hypothesis of aqueous deposition. The pebbles may, perhaps, have been derived from neighboring prominent points in the till during the progress of a submergence. The action of floating ice may be postulated as an accompaniment of submergence

whether the water be shallow or deep, and this may have carried stones in sufficient number to have supplied the clay with the few pebbles that it contains. The difficulties arising from the great range in altitude which the deposit presents may not be fatal to the hypothesis of submergence. The hypothesis is, therefore, still entertained, especially since none more satisfactory has suggested itself, but it can not be confidently put forward as a solution.

In considering the time relations of this clay, there is decisive evidence that it was deposited at a much later date than the Kansan sheet, in the fact that it also overlies the Illinoian, a younger sheet of drift. The evidence is equally conclusive from its relation to terraces cut in the Kansan. The gummy clay, as well as its coating of loess, is found on terraces bordering valleys cut in the Kansan sheet, and also on the uplands occupied by that sheet. All the main valleys examined in southeastern Iowa had been cut to a depth of 50 feet or more into the Kansan sheet, and often to a width of 1 or 2 miles, prior to the deposition of this clay. If, therefore, it had been examined only in districts outside the limits of the Illinoian, it might have been demonstrated to be a much younger deposit than the Kansan.

Passing to the Illinoian sheet, it is found that the changes effected in its surface prior to the deposition of the clay under discussion are less than in the Kansan, yet some change was apparently effected in its surface. In fact, the surface of the till has often the appearance of marked atmospheric reddening prior to the deposition of the gummy clay, and there is usually an abrupt change from gummy clay to the till. The till is also not infrequently leached of its calcareous material for several feet below the base of the gummy clay. In places the gummy clay is mingled with the underlying till, but it does not follow that the two deposits are contemporaneous. The Illinoian till sheet was not so conspicuously channeled by streams prior to the loess deposition as the neighboring portion of the Kansan, but the slight channeling which took place seems to have antedated the deposition of the gummy clay as well as that of the overlying loess. This clay is apparently more conspicuously developed in small channels cut in the Illinoian than on the bottoms or terraces of the broad channels. Not infrequently these small channels are so greatly filled by the clay that the surface is nearly restored to its original planeness. The writer has found

numerous exposures where such filling reaches a depth of 15 or 20 feet in districts where the general thickness of the gummy clay is scarcely 5 feet. The presence of so many exposures where there is evidence of an interval between the deposition of the till and that of the clay under discussion has led the writer to conclude that in the exposures where the two deposits appear to be blended there has been redeposition of the till in connection with the later deposit. In so commingled a sheet as till it is a very difficult matter to determine whether redeposition has occurred since the withdrawal of the ice sheet. In view of all the data now available the conclusion seems warranted that this clay is somewhat younger than the Illinoian.

No suitable name has as yet been found for the clay, although the name *gumbo* has been applied to it by residents of the region which it characterizes, because of its gummy character. This name is open to objection for the reason that it has already been applied to other deposits of different age and different origin. There is a gumbo in the Cretaceous series of the Western plains. The term is also applied to the flood-plain deposits of the Illinois and Mississippi, which are still in process of accumulation. The name gumbo has, however, been used by McGee in his discussion of a compact phase of the loess found in southeastern Iowa and northern Missouri, and of a dark clay at its base, apparently the clay under discussion. It is his opinion that the loess there owes its compactness to derivation from the clay beneath it.[1] Until the origin and time relations are more satisfactorily determined, it may be as well to leave unsettled the name for the deposit.

It remains to consider the probable time relations between the clay under discussion and the sheet of loess that overlies it. The gummy clay, as noted above, has usually a blackened surface due to humus, a feature which indicates that it was exposed to conditions favorable to plant growth. The plant remains in this clay are seldom sufficiently well preserved to admit of identification. The writer, however, found bits of wood in an exposure along the Santa Fe Railway near New Boston, in Lee County, Iowa, which have been identified by Mr. F. H. Knowlton, of the United States National Museum, as a species of conifer. The specimens were too small and not sufficiently well preserved to enable him to determine the genus and species, though they appear to belong to the genus Picea (spruce).

[1] Eleventh Ann. Rept. U. S. Geol. Survey (for 1889-90), 1891, pp. 299, 414, 461-471, 508-510.

They consist of rootlets about 2 cm. in length and 2 mm. in diameter. They are, therefore, too small to afford good sections of the wood cells. The locality where these specimens were obtained is now a prairie region and the spruce tree is not native in the forests which border the streams, the only conifer present being the red cedar. Several instances of the occurrence of logs at the base of the loess in western Illinois have been reported to the writer by well drillers, but no specimens have been obtained. The evidence is, however, considered good that much of this region was forest-covered prior to the deposition of the loess. Whether this emergence and forest growth occupied a long period has not been satisfactorily determined.

Last season (1897) the writer found a fine exposure of muck and peat and wood, associated with silt, at the base of the loess in a cutting on the Toledo, Peoria and Western Railway, 4 miles west of Washington, Illinois, a photograph of which is presented in Pl. XI, *B*. It is several miles inside the border of the Wisconsin drift, and the loess is here covered by a bed of till of Wisconsin age. At this cutting the Wisconsin drift is only 15 feet in thickness, the upper portion having been removed by erosion. The section at the cutting is as follows:

Section at a cutting on the Toledo, Peoria and Western Railway, 4 miles west of Washington, Illinois.

	Feet.
Gravel	6
Blue till (Wisconsin)	8
Gray clay, laminated, pebbleless, very calcareous	1
Brown loess, probably of Iowan age, calcareous, and containing helix shells	6
Peaty silt of brownish black color, containing a large amount of wood (Sangamon)	5
Drab colored loess-like silt, becoming brown toward bottom, filled with mats of fibrous roots	4–5
Reddish-brown leached till (Illinoian)	4
Brown unleached till (Illinoian) exposed	8
Total	42

Specimens of the shells in the loess, of the wood in the peat, and of the roots under the peat have been collected, but have not been specifically identified. The silt under the peat is somewhat similar to the deposit which overlies it, though it may prove to be of different origin. This series of beds seems to indicate that a land surface, which had been exposed to atmospheric action favorable for leaching of the till, was transformed into a swamp favorable to the growth of peat, and that this swampy condition was followed by the deposition of the loess. As the gummy clay just dis-

cussed is not represented in this section, the question naturally arises whether the silty material under the peat is not its equivalent. The question can scarcely be decided from such fragmentary evidence as is now available. This section appears to bring the loess into closer relation to the gummy clay than had heretofore been supposed. If the blackened, humus-stained surface of the gummy clay required but a few centuries for its development, it would seem not unlikely that the deposition of this gummy clay and that of the loess are to be referred to the same epoch of low altitude, an epoch attended by more or less complete submergence, with interruptions or partial emergence of the land. The reddened and leached surface of the Illinoian till apparently signifies a long exposure to atmospheric action. The balance of evidence seems to favor a closer connection between the loess and the gummy clay than between the latter and the underlying Illinoian till.

As the loess is discussed in some detail in connection with the Iowan drift sheet, with which it is correlated, only a general statement concerning it is made at this point. The entire surface of the Illinoian drift sheet appears to have received a capping of loess or loess-like silt at about the time of the Iowan ice invasion, the deposit being found midway between the principal streams as well as along their borders, where it was first recognized. It is much thicker on the borders of the Illinois and Mississippi than on the divide between these streams or in the region east from the Illinois. In much of southern Illinois the thickness is only 3 to 5 feet, and the average thickness in districts east of the Illinois and Mississippi is probably less than 10 feet. On the borders of these streams its thickness is frequently 30 to 50 feet, though a portion of the valley border near the corners of Iowa, Missouri, and Illinois is characterized by a thinner coating of loess than is found to the north or south, the average thickness being scarcely 10 feet. Aside from its thickening on the borders of the Illinois and Mississippi, there is also a thickening on the borders of the Iowan drift sheet in Carroll, Whiteside, Henry, and Bureau counties, as indicated in the discussion of that drift sheet.

Sections of the Illinoian drift.—For sections illustrating the structure of the Illinoian drift sheet, reference may be made to the portion of this report devoted to the wells of Illinois (Chapter XIV). The well sections are taken up by counties, but attention is called to the several drift sheets which are

penetrated by the wells in the various counties of the State. The structure of the portion of the Illinoian drift in southeastern Iowa and western Illinois is set forth in the detailed discussion of the border of the Illinoian drift sheet which follows.

THE DRIFT BORDER.

DISTRIBUTION.

The border of an old drift sheet, tentatively referred to the Illinoian, emerges from beneath the Wisconsin drift in southern Wisconsin a few miles southwest of the city of Madison, and from that point southward to the Mississippi River it forms the eastern border of the Driftless Area of southwestern Wisconsin and northwestern Illinois. The border of this drift sheet probably crosses the Mississippi a few miles below Savanna, but, as shown in Pls. VI and XII, the presence of the Iowan drift sheet, together with the heavy loess deposit, both of which are later than this drift, has so obscured it that its limits can not well be determined in Clinton and Scott counties, Iowa. In Muscatine County, Iowa, the slightly ridged western border of the Illinoian drift sheet becomes visible, and is distinctly developed from that county southward. It crosses the Iowa River just below Columbus Junction and leads southward through western Louisa County, the village of Cairo being within a mile and the village of Morning Sun within 3 or 4 miles east of the border. It passes thence in a course west of south across northwestern Des Moines County and southeastern Henry County, the villages of Yarmouth and New London being situated on the ridged border and the village of Lowell, in Skunk River Valley, being situated where the border crosses that valley. In Lee County, as shown in fig. 4, the course of the ridge is southward past the village of West Point to the vicinity of the Mississippi bluff, about 5 miles below Fort Madison. From this point southward to Keokuk the border apparently is nearly coincident with the course of the Mississippi River, though there may be slight deposits of the Illinoian drift on the west side of the valley. Immediately south of Keokuk, on the Illinois side of the river, a distinct ridge of drift appears which marks the border; and this may be traced southward along the east bluff of the Mississippi across Hancock and Adams counties, though in the southern portion of Adams County it lies back a mile or two east from the river bluff. In Pike County the border bears gradually away from the Mississippi bluff in

a southeastward course and comes to the Illinois River in the southeast part of the county; thence it follows the Illinois Valley southward to the mouth of the river, perhaps touching the west bluff in southern Calhoun County. The border then either follows the Mississippi bluff eastward past Alton, or continues southward across the projecting point of Missouri which borders the mouth of the Missouri River just above St. Louis. It is somewhat uncertain whether the drift found on the Missouri side of the Mississippi is of direct glacial deposition or a deposit made by streams; the greater part of it is assorted material. The presence of drift on the Missouri side of the Mississippi has been noted only in the district north from the city of St. Louis. Below that city the drift border apparently follows the line of the valley of the Mississippi closely as far down as southern Jackson County. The Mississippi River there turns southward, but the drift border passes eastward, following the north slope of the elevated ridge which crosses southern Illinois and entering Indiana in the extreme southwest corner of that State.

The drift border, as indicated on Pl. VIII, crosses the southwestern county of Indiana (Posey) in a northeastward course lying near the valley of the north fork of Big Creek. It cuts across the northwest corner of Vanderburg County and enters Gibson County in sec. 16, T. 4 S., R. 11 W. Thence it passes northeastward, touching the village of Haubstadt and coming to Pigeon Creek in sec. 22, T. 3 S., R. 10 W., at the junction of Sand Fork and Muddy Fork. From this creek the course for a few miles is northward to the divide between Pigeon Creek and Patoka River, which it crosses about 4 miles east of Princeton. It there swings eastward and comes to Patoka River near the line of secs. 32 and 33, T. 1 S., R. 9 W. It enters Pike County about 1 mile south of Oatsville, in sec. 27, T. 1 S., R. 9 W. In that county it lies but a short distance north of Patoka River, and apparently follows nearly the divide between the small northern tributaries and Flat Creek, a large northern tributary, to the mouth of Flat Creek in western Dubois County. From this point eastward to the vicinity of Jasper, and thence northward to East White River, there is a sand-covered plain in which the boundary is difficult to locate. Possibly this plain was covered by the ice sheet, since glacial pebbles several inches in diameter are found beneath the sand on its east border. The sand seems to have been deposited in a small glacial lake, Lake Patoka, which occupied this

plain and neighboring sections of the Patoka Valley while the present outlets along the White and Wabash rivers were blocked by the ice sheet.

For a few miles north from East White River the exact position of the glacial boundary is difficult to locate, for only scattering pebbles are found along the border. It seems, however, to pass near the village of Alfordsville, in Daviess County, and thence to take a northeastward course to the bluff of East White River near Whitfield, in Martin County. The border follows the west bluff of East White River northward past Mount Pleasant to the bend near that village, from which point it continues northward, passing about a mile east of the village of Loogootee. The border then bears west of north and soon enters the western range of sections in Martin County and lies very near the Martin-Daviess county line for 10 or 12 miles. It makes a slight protrusion eastward at the valley of Furse Creek, in northwestern Martin County, and enters Greene County about a mile southeast of the village of Scotland.

The course of the glacial boundary through Greene, Owen, and Monroe counties has been mapped in detail by Mr. C. E. Siebenthal, of the Indiana Geological Survey, and is represented in Pl. IX. From near Scotland it has a course slightly east of north to the valley of Plummer's Creek, in sec. 9, T. 6 N., R. 4 W. North of this creek it makes an eastward protrusion of about 2 miles into a lowland tract known as the American Bottom, reaching sec. 36, T. 7 N., R. 4 W. North of this lowland the course of the boundary is west of north to the valley of Richland Creek, in sec. 9, T. 7 N., R. 4 W. It follows the east bluff for about 3 miles and crosses to the west side of the creek in sec. 35, T. 8 N., R. 4 W. It follows nearly the west bluff to sec. 17, T. 8 N., R. 3 W., passing about a mile southeast of the village of Newark. The boundary makes an eastward protrusion of about a mile into Richland Creek Valley in sec. 16, from which the course is northward into Owen County. Entering Owen County in sec. 33, T. 9 N., R. 3 W., the boundary leads northeastward past Freeman post-office and crosses into Monroe County in sec. 6, T. 9 N., R. 2 W. The course continues northeastward through northern Monroe County, the boundary being about 2 miles north of Ellettsville and 1 mile north of Modesto, and coinciding nearly with Indian Creek Valley from mouth to source. From the head waters of Indian Creek, in sec. 3, T. 10 N., R. 1 W., the boundary leads eastward about 6 miles, near the Monroe-Morgan

county line, and there reaches its most northern point in Indiana. It is here that the limits of the portion of the ice sheet properly included in the Illinois glacial lobe should be placed. The boundary from there leads southeastward to the Ohio Valley, and is discussed in another report in preparation. The drift border shows no evidence of an overlapping at this reentrant angle of one lobe upon territory abandoned by the other, such as was noted on the west side of the Illinois lobe. The border southeast from the reentrant seems to be a direct continuation of that just traced.

The length of the drift border thus outlined is about 700 miles, and the width of the lobe encircled by it is about 300 miles. The tracing of this border has been the product of several independent surveys. The portion in Wisconsin was largely determined by members of the Wisconsin Geological Survey. The border in northwestern Illinois was partly determined by members of the Illinois Geological Survey, and subsequently with greater approximation by Prof. R. D. Salisbury, of the United States Geological Survey, but the precise limits have not as yet been mapped. The portion in Iowa, and also the portion from the southern edge of Iowa southward to the vicinity of St. Louis, have been traced by the present writer. Salisbury, however, made observations at an earlier date on the limits of the drift in Pike and Calhoun counties, Illinois, and discovered evidence suggesting that a portion of these counties is unglaciated. The deposits of drift on the Missouri side of the Mississippi, in the vicinity of St. Louis, were first described by Prof. A. H. Worthen[1] and later by Profs. G. F. Wright,[2] J. E. Todd,[3] and H. A. Wheeler.[4] The portion of the boundary from St. Louis southward to Jackson County, Illinois, was mapped by Prof. G. F. Wright and discussed in Bulletin 58 of this Survey. Wright also mapped the boundary across southern Illinois, but this had previously been outlined with a fair degree of approximation by Worthen.[5]

Wright also made a tracing of the glacial boundary in southwestern Indiana, which was published in Bulletin 58 of this Survey. But the position of the boundary in that region is found to be shown very inaccurately, the limits of the drift being from 5 to 20 miles outside the limits placed by

[1] Geol. of Illinois, Vol. I, 1866, p. 314.
[2] Bull. U. S. Geol. Survey, No. 58, pp. 72–73.
[3] Bull. Geol. Soc. America, Vol. V, 1894, p. 539. Missouri Geol. Survey, Vol. X, 1896, pp. 161–163.
[4] Trans. St. Louis Acad. Sci., Vol. VII, No. 3, Feb., 1895.
[5] Geol. of Illinois, Vol. I, 1866, p. 27.

Wright. As indicated above, its position in Monroe, Owen, and Greene counties has been mapped in detail by Mr. C. E. Siebenthal, of the Indiana Survey. The portion between Greene County and the southwest corner of Indiana has been traced by the present writer. The portion mapped by Siebenthal has been reconnoitered by the present writer, and also most of the border in southern and southwestern Illinois.

TOPOGRAPHIC EXPRESSION.

The drift border in the portion examined by the writer, both in southeastern Iowa and in western Illinois, is generally marked by a low ridge, seldom rising more than 60 feet above the outer border district, and averaging perhaps 40 feet. In Adams and Pike counties there are a series of ridges shown on the glacial map (Pl. VI), which have nearly parallel trend, but which are broken by wide gaps, and represent imperfectly the successive positions of the ice margin in these counties. The ridge forming the border seldom exceeds 2 miles, and is usually but a mile or less in width. On the eastern slope there are low swells, 10 to 20 feet in height, extending out in places to a distance of several miles from the drift border, but seldom showing a disposition to form connected chains or ridges.

The portion of the drift border along the east side of the Driftless Area in northern Illinois and southern Wisconsin is in places slightly thickened beyond the usual depth of drift in districts to the east, but is in other places very thin. It may be possible to trace an ill-defined ridging more or less successfully near this border. The writer's observations touch it at only a few points, and are not sufficiently full or continuous to justify an opinion on this matter.

From the point where the border crosses the Illinois River in southeastern Pike County, Illinois, southward to the Mississippi, there are occasional knolls, 20 to 40 and occasionally 60 feet in height, the majority of which are elliptical, with the longer axis trending ENE.-WSW., or about at right angles to the trend of the drift border. These knolls do not lie at the extreme border, but are situated 5 to 10 miles or more back from it. Their form is drumlinoid, but seldom assumes the regularity of the typical drumlin.

The portion of the drift border touching the State of Missouri displays only patchy deposits of drift, usually in the valleys or depressions, and

seldom, if ever, aggregated in the form of knolls or ridges. As noted above, it is not certain but that the deposition was largely made by streams, rather than by direct glacial action.

Below St. Louis there is a less regular and lighter deposit of drift in the vicinity of the border than in districts to the north, and the border there, so far as noted, is without topographic expression, the drift being found largely in depressions, with only a thin veneering on the hills. As noted farther on, a prominent belt of drift ridges comes down nearly to the drift border from the northeast across southeastern Madison, central St. Clair, eastern Monroe, and northern Randolph counties, and there turns southeastward, taking a course nearly parallel with the drift border and scarcely 10 miles back from it. Upon turning southeastward this belt of ridged drift becomes ill-defined, but has been traced with some certainty to central Jackson County (midway between Ava and Murphysboro). As yet no line of ridges marking a continuation has been found farther southeast. It is possible that the sheet of drift which terminates at this belt of ridges may come to the glacial boundary in southern Illinois, and constitute that boundary from there eastward.

In southern Illinois occasional low knolls, 20 feet or less in height, occur in the vicinity of the drift border, and there appears to be a slight ridging in east-west direction in the southern portion of Williamson County, a ridging sufficient to influence the course of streams, as indicated on a later page (p. 527). In the vicinity of the Wabash River, near Ridgway, and thence northeastward to New Haven, Illinois, there is a belt of low sandy knolls and ridges, the origin of which is not clearly determined. Possibly they are entirely the result of wind action, or they may be due in part to glacial action.

In southwestern Indiana a few places were found where the drift border and districts immediately back of it show a tendency to aggregation in low knolls and ridges. Perhaps the most conspicuous instance is found in Gibson County, near Fort Branch, where for a distance of about 3 miles along the east side of the Evansville and Terre Haute Railway there is a ridge of drift 30 to 50 feet in height and nearly a mile in breadth, whose surface is quite undulatory. From the southern end of this ridge southwestward into Posey County knolls 10 to 20 feet in height are of frequent occurrence, and in places become so closely aggregated as to give a

decidedly morainic expression to the drift surface. Occasional knolls and low ridges of drift were found in northeastern Gibson and northern Pike counties, Indiana, lying usually within 5 miles of the glacial boundary. No knolls or ridges of drift were noted in the district north of East White River, nor have any been observed far back from the glacial boundary in southwestern Indiana and southern Illinois.

Reviewing the above statements, it appears that the border is only in places marked by a definite ridge, and that there the ridge has mild expression and slight dimensions compared with the expression and dimensions of the bulky moraines formed at the Wisconsin stage of glaciation. The expression is also much milder than that of ridges formed at some distance back from the drift border in southwestern Illinois, which pertain to the Illinoian sheet, descriptions of which are given below.

STRUCTURE OF THE DRIFT BORDER.

The drift border, as here discussed, includes a belt several miles in width, embracing a sufficient amount of territory to afford a fair index of the variations which are displayed in the immediate vicinity of the border.

The discussion begins in Lee County, Iowa, which is the writer's native county, since the sections of wells and also natural exposures have been studied more thoroughly there than at any other part of the drift border. This county is situated in the extreme southeast corner of Iowa. (See fig. 4). During the drought of 1894 and 1895 a large number of new wells were sunk, and the writer had opportunity to make many observations concerning the character of the drift penetrated by them. The Illinoian drift sheet is found to be generally but 10 to 30 feet in thickness, though on the ridge which forms its western limit the thickness is increased to 50 feet or more. In several of the wells which were observed during excavation the Illinoian drift is composed of a brownish, pebbly clay, which has been so thoroughly leached that no response with acid could be obtained, even where the thickness is 20 feet. But in some of the wells this sheet contains a very calcareous till which has been leached only to a depth of 6 or 8 feet. This variability in the amount of leaching is thought to be due to difference in the derivation of the material. That which is leached from top to bottom is probably made up in large part of the surface portion of the older sheet of drift which is here overridden. That which is a typical calcareous till

was probably in part formed by the ice in passing over rock ledges and in part collected from the calcareous portions of the underlying sheet. It does not seem at all probable that the variations in the depth of the leached material are due entirely to leaching which has occurred since the Illinoian sheet was deposited. The portions which are leached to great depth seem to be no more readily pervious to water than those in which the leaching has extended to a depth of only 6 or 8 feet.

The ridge marking the western limits of the Illinoian drift, in Lee County, is in places thickly set with bowlders, but as a rule it appears to carry no more bowlders than the portion of the same sheet in the plain tracts immediately east. The bowlders and smaller rock constituents of the Illinoian drift are found to differ somewhat from those of the sheet that underlies it, there being certain rocks found in it that are not found in the underlying sheet, while other rocks differ in abundance in the two sheets. Several bowlders of red jaspery conglomerate, apparently from the Huronian outcrops north from Georgian Bay, have been found in this county on and east of the ridge that marks the western limits of the Illinoian drift, and these are thought to point decisively to the Labradorian invasion. There are also quartzite rocks present in the Illinoian drift that have not been seen in the sheet beneath it and which probably were derived from sources not far distant from the Huronian that bears the jaspery conglomerate. The cherty beds of the Burlington limestone that outcrop along the Mississippi and its tributaries have been incorporated in the Illinoian drift sheet and transported westward to the extreme limits of that sheet. They point with certainty to the influence of the Labradorian invasion.

The Illinoian till sheet in Lee County, as also in counties to the north, is separated from the underlying Kansan till sheet by a weathered zone accompanied by beds of black muck and peaty material. This was first brought to the writer's notice about ten years ago, in a well sunk near the village of Yarmouth, in Des Moines County. For this reason, and because it is not liable to be a source of confusion by duplication in other parts of the glaciated region, the name Yarmouth has been proposed to cover the interglacial interval between the Kansan and Illinoian.[1] The village of

[1] The weathered zone (Yarmouth) between the Kansan and Illinoian till sheets, by Frank Leverett: Proc. Iowa Acad. Sci., Vol. V, pp. 81-86, 1898; Jour. Geol., Vol. VI, 1898, pp. 238-243.

Yarmouth is situated about 20 miles northwest of Burlington, the county seat of Des Moines County, on the line of the Burlington and Western Railway. It stands on the ridge which marks the western border of the Illinoian till sheet. The well above referred to, which first suggested to the writer the occurrence of two distinct sheets of till in southeastern Iowa, was made by William Stelter, on the border of the village of Yarmouth. The writer visited the well soon after it was bored and made out the following section from the material exposed in the dump:

Section from well of William Stelter, near Yarmouth, Des Moines County, Iowa.

	Feet.
Soil and loam (Iowan loess)	4
Brownish yellow till (Illinoian)	20
Gray till (Illinoian)	10
Peat bed with twigs and bones (Yarmouth)	15
Gray or ashy sandy clay, containing wood (Yarmouth)	12
Fine sand (Yarmouth)	16
Yellow sandy till with few pebbles (Kansan)	33
Total depth	110

The bones found in the peat were sent to the Smithsonian Institution and there identified by Dr. F. W. True, as follows:

(1) A portion of the pelvis and the upper part of the femur of the wood rabbit (*Lepus sylvaticus*); (2) the scapula of the common skunk (*Mephiticus mephitica*). The occurrence of these bones was first announced by McGee, in the Eleventh Annual Report of this Survey, and referred to a "forest bed," but without more definite reference.[1]

The thickness of the peat in this well and of the associated sandy clay charged with wood, is an impressive evidence of an interglacial interval of considerable length. But in the writer's opinion it furnishes less weighty evidence than is afforded by the general weathering which took place on the surface of the Kansan sheet prior to the deposition of the Illinoian drift. The peat naturally arrests attention quicker than the reddened zone, but is more restricted in its development; yet several instances of the occurrence of beds such as the one at Yarmouth have been brought to the writer's notice. They appear to be rather more prevalent along the extreme border of the Illinoian than at points some miles back beneath it; but instances occur all over the portion of southeastern Iowa invaded by the Illinois lobe.

[1] See p. 495 of report cited, published in 1891.

The peaty deposits are usually found associated with sandy beds, while the soil and weathered zone cap a sheet of till or stiff clay.

In many of the wells in southeastern Iowa, and also in natural exposures, a reddened or deeply oxidized clay is found, instead of peat or muck, between the Illinoian and Kansan sheets. This constitutes usually the weathered surface of the Kansan, and appears to have been originally a calcareous till, like the remainder of that deposit. Acid tests have frequently been made in freshly dug wells and in natural exposures with a view to determine the amount of leaching prior to the deposition of the Illinoian till sheet. It is found that, as a rule, no response to acid is obtained at less than 4 feet, and often the response does not set in within 6 feet of the top of the buried Kansan sheet. In the cases where leaching occurs within 4 feet of the surface, it seems safe to infer that a portion of the leached material had been removed prior to the deposition of the Illinoian till sheet. While the leached material usually bears a striking resemblance to the underlying calcareous till, exposures have been found in which it differs in general appearance and is perhaps a deposit of different origin. These deposits also are thoroughly leached at surface. This weathered zone is so conspicuous throughout the region of overlap of the Illinoian upon the Kansan that the writer has satisfied himself of the occurrence of a long interval of deglaciation prior to the deposition of the Illinoian drift. Instances of the occurrence of this weathered zone, and also evidences of erosion between the Kansan and Illinoian glaciations, are presented below.

With this brief explanation of the drift border in the part most familiar to the writer the discussion will pass to the north part of the border in southern Wisconsin, and proceed thence southward.

From the descriptions of the drift in southern Wisconsin, presented in the Geology of Wisconsin and in Chamberlin and Salisbury's paper in the Sixth Annual Report of this Survey, it appears that the drift border is characterized by occasional gravelly knolls and ridges, some of which are of distinct esker type. There are also gravel and sand deposits on plane-surfaced tracts, but the greater portion of the drift appears to be a moderately stony till with an adhesive clayey matrix. This phase of the drift border continues southward across northwestern Illinois. It is found that some of the preglacial valleys near the drift border were filled with a deposit of fine silt or clay containing very few pebbles. These deposits characterize

valleys which had eastward drainage in preglacial times and are probably to be attributed to the ponded waters held in front of the ice and laden with large amounts of fine sediment carried by the waters issuing from the ice. Portions of the border in northwestern Stephenson, southeastern Jo Daviess, and northwestern Carroll counties are liberally strewn with bowlders of granite and other distantly derived rocks. The number appears to be greater within the first 5 miles back from the drift border than at more remote points. In this portion of the drift border the loess coating is thin except in the immediate vicinity of the Mississippi Valley, its average depth being scarcely more than 5 feet. On slopes it is largely removed, leaving the surface of the glacial drift exposed to view.

The interval between the southern point of the Driftless Area near Savanna and the northernmost point at which the Illinoian drift border is recognized on the Iowa side of the Mississippi is about 50 miles. A direct line across it traverses a low plain covered with a very bowldery sheet of Iowan drift, described by McGee, which is nearly free from deposits of loess in the middle portion, but which is bordered in the peripheral portion on the north east and south by loess-covered drift. No recognition of the Illinoian drift has been made in this interval along the direct line of connection. But it has been identified in Davenport and at points west of that city in Scott and eastern Muscatine counties, Iowa. It is therefore certain that the Illinois lobe extended beyond the Mississippi River at least as far north as eastern Scott County.

Prof. J. A. Udden has recently published an important table showing notable differences in the rock constituents of the Illinoian and the underlying drift sheets of Muscatine County, from which it appears that the constituents of the Illinoian are largely derived from outcrops to the east.[1]

Exposures of drift in Davenport and Muscatine, Iowa, were made the subject of joint investigation by Prof. Samuel Calvin and Dr. H. Foster Bain, of the Iowa Geological Survey, Prof. J. A. Udden, and the writer, in November, 1897, and there was entire unanimity in the interpretations. At Davenport the first exposure examined was one previously described by McGee,[2] which is situated at the northwest corner of Sixth and Harrison

[1] Iowa Geol. Survey, Vol. IX, 1899, p. 336.

[2] Eleventh Ann. Rept. U. S. Geol. Survey (for 1889-90), 1891, p. 491; also fig. 77.

streets. The occurrence of a distinct soil and weathered zone between the loess and the upper or Illinoian till sheet is a feature not noted by McGee; with this exception his description applies well to the exposure. The section, as determined November, 1897, is as follows:

Section of drift at corner of Sixth and Harrison streets, Davenport, Iowa.

	Feet.
Iowan loess, partly eroded	8
Black soil 1 foot, with Illinoian till surface leached and reddened to a depth of 3 feet in the Sangamon interglacial stage; total	4
Brown calcareous till, with a few calcareous nodules; traces of horizontal bedding near bottom, but with few vertical fissures or seams, a characteristic Illinoian till	7
Brown till, calcareous, with numerous vertical fissures and seams, and occasional horizontal sand partings, with tendency to break in cubical blocks, a characteristic oxidized Kansan till	8–10
Blue-gray till, calcareous, with occasional horizontal sand partings and numerous vertical seams, also tendency to break in cubical blocks; bowlder-like masses of gravelly sand often 2 or 3 feet in diameter, in some cases showing crumpling of beds, occur in the lower part of the exposure; a characteristic unoxidized Kansan till; entire depth	35–40
Fine sand, appearing only on Harrison street, at base of exposure	3
Total, about	70

The base of this exposure stands about 50 feet above the level of the Mississippi River, while the top of the exposure is nearly at the level of the uplands. In this exposure no leached zone appears at the junction of the Illinoian and Kansan, probably because of removal by the Illinois ice lobe. The change in physical character upon passing from the brown till of the Illinoian to that of the Kansan is very striking. The Illinoian may be denoted a friable or crumbling till, while the Kansan is a caking till where characteristically developed.

The next exposure examined presented a weathered zone and evidence of erosion between the Illinoian and Kansan, and also showed the Iowan loess in its full thickness. It is found along Eighth street in a steep descent between Myrtle and Vine, and is as follows:

Section of drift along Eighth street, between Myrtle and Vine streets, Davenport, Iowa.

	Feet.
Iowan loess	30
Reddish-brown surface of Illinoian till sheet, leached and stained during Sangamon interglacial stage	2½ to 3
Brown calcareous till, crumbling readily; a characteristic Illinoian till	15
Ash-colored gummy clay with black streaks, apparently of humus, representing the Yarmouth interglacial stage	2 to 3
Brown till, calcareous, fracturing in cubical blocks, color changing to grayish blue at 12 to 15 feet; characteristic Kansan till	25
Total, about	75

The surface of the Kansan appears to have been subjected to some erosion, for it drops down about 15 feet in a distance of 20 rods in passing toward the river valley. This sloping surface of the Kansan is leached and humus stained, and the Illinoian till mantles it with a bed of nearly uniform thickness, thus presenting an upper surface nearly parallel with that of the eroded Kansan.

In the autumn of 1894 the writer observed several exposures of a soil and weathered zone in ravines in western Scott and eastern Muscatine counties, between what are interpreted to be the Kansan and Illinoian till sheets. They are not conspicuous in eastern Muscatine County, but may be seen both north and south of Blue Grass, in Scott County. The exposures noted are not sufficiently deep to show the lower till sheet to good advantage, but the upper is well displayed and has the characteristic appearance of the Illinoian. Its thickness is but a few feet—in some places only 6 or 8 feet, and seldom more than 15 feet. The Yarmouth soil and weathered zone is represented by a gummy black or gray clay, changing below to a reddish-brown till. The Sangamon soil and weathered zone is represented by a similar dark gummy clay and a leached and reddened till surface. The Iowan loess in this locality is only about 8 feet in depth, and is more compact than the bluff loess found in Davenport.

At Muscatine the party of geologists above mentioned examined exposures in the east part of the city, in the east bluff of Mad Creek, and east from there on or near Second street and on Park avenue. These all occur in a lowland tract bordering the lower course of the creek and occupying the interval between the creek and Mississippi River. Its general elevation is about 80 feet, and the highest points barely reach 100 feet above the low water in the river. The latter are found in a low ridge following the bluff of the Mississippi. This lowland carries on its surface a nearly pebbleless silt several feet in depth, at the bottom of which there are occasional thin deposits of sand resting on till. The thickness of silt and sand is scarcely 10 feet, or less than one-half of the thickness of the Iowan loess on neighboring uplands. It seems doubtful whether the deposit is of Iowan age or is to be correlated with the loess. The view that it is alluvial seemed to us more probable. The till beneath this silt and sand was found to carry numerous large bowlders, some of them being

at its surface. It also presents the crumbling texture characteristic of the Illinoian till sheet. It shows very little surface leaching, response to acid being readily obtained at a foot or less. This absence of a marked weathered zone was interpreted to be due to removal by a stream which deposited the sand and silt, rather than to the time interval being too brief for the development of a weathered zone. The slight inequalities in its surface appear to be due to erosion. This till is referred with some confidence to the Illinoian because of its physical texture and characteristics. Its thickness, as exposed on Second street, is about 30 feet. Beneath the till there are beds of fine sand and silt, in the midst of which are thin layers of clay, bearing pebbles up to 2 inches or more in diameter. Similar beds in the southwest part of Muscatine separate the Illinoian and Kansan till sheets, as shown below.

In the southwest part of Muscatine the altitude of the Mississippi bluff is 160 to 200 feet above the river, and a remarkably full series of drift deposits is, or has been, exposed. In 1894 a grading on Green street afforded an excellent exposure of the upper part of the series, beginning at a level about 165 feet above the river and extending down 50 feet, but this is now concealed by grass. The lower part of the bluff is still exposed in the large clay and sand pits west of Green street. The exposure on Green street was examined by the writer when freshly graded (in 1894), and those west of Green street were examined by the party of geologists in November, 1897. The sections are as follows:

Section on Green street, Muscatine, Iowa.

	Feet.
Iowan loess, partly eroded	10
Brownish-black silt at base of loess	1½ to 2
Pebbly black soil (Sangamon)	3
Leached brown till (Illinoian)	6
Brown till, unleached, many bowlders near base (Illinoian)	12
Calcareous silt	6 to 8
Calcareous till of brown color, probably Kansan	10

Section on Mississippi bluff west of Green street, Muscatine, Iowa.

	Feet.
Loess, perhaps not in situ	0 to 5
Till of brown color, eroded, of friable crumbling texture, characteristic of Illinoian drift	15 to 25
Beds of sand with even upper surface but uneven lower surface, containing a few bowlderets and cobblestones, but not as a rule stony	5 to 12
Gray till, with vertical cracks lined with brown material, probably Kansan	8 to 20

Section on Mississippi bluff west of Green street, Muscatine, Iowa—Continued.

	Feet.
Disturbed beds of sand with folds that appear to have a prevailing east-west trend, as if shoved from the north	4 to 12
Blue-black till with fragments of wood, very thickly set also with small stones and very calcareous, not characterized by weathered seams, possibly pre-Kansan, exposed only a few rods	0 to 8
Peaty bed, exposed only for a few feet	½ to 1
Sand, perhaps from decomposed Coal Measure Sandstone	1 to 2
Coal Measure Sandstone exposed at bottom of pit at level probably 50 feet above river.	
Total	60

The blue-black till at the base of this exposure is thought by Bain to be very similar in physical texture to some of the supposed pre-Kansan deposits of southern Iowa. The writer has observed several instances of similar material near the bottom of the drift series in southeastern Iowa. It is thought best not to include it in the Kansan unless these suspicions are removed.

In the Muscatine cemetery, on the bluff back of the exposures just described, at an altitude about 200 feet above the river, a well passed through 215 feet of glacial deposits, including loess and sand. The drift is mainly blue till, but beds of sand such as outcrop in the exposures near Green street were passed through.

For a few miles in the portion of the Illinoian drift border adjacent to the southwestern flowing portion of Cedar River, in Muscatine County, sand dunes and a general coating of sand, drifted probably by wind from the plains bordering the Cedar River, form a mantle of considerable depth on the crest of the terminal ridge, and conceal the structure of the ridge, so that wells afford the only means for obtaining information concerning it. Several deep wells have been made which penetrate from 120 to 300 feet of drift, the least depth at which rock was found being 120 feet. These wells usually penetrate a large amount of till, but there are thin beds of sand associated with the till at various levels. In some cases a hard till is found at considerable depth, which, it is probable, is as old as the Kansan, and possibly is pre-Kansan in age. The following list of wells in Muscatine County will serve to set forth the variations in structure and the great depth of drift. The list begins at the northeast part of the county and proceeds southwestward along the ridge. For several of the sections the writer is indebted to Prof. J. A. Udden.

Deep wells along Illinoian drift border in Muscatine County, Iowa.

Owner or location.	Altitude above tide.	Depth.	Remarks.
	Feet.	*Feet.*	
S. Hayden, sec. 8, T. 78, R. 1 E	800	120	Mainly till; inflammable gas from near bottom of drift.
Sec. 33, T. 78, R. 1 E	730	261	Clay, 80 feet; quicksand, 8 feet; coarse sand near bottom.
Sec. 9, T. 78, R. 1 W	710	240	Sand, or sandy till, 90 feet; blue clay, 140 feet; sand and gravel, 10 feet.
W. Feldholm, 2 miles south of Durant.	750	100	Silt, 5 feet; sand, with few pebbles, 30 feet; hard blue till, 65 feet.
Three miles south of Wilton	720	300	No rock entered.
J. Denkman, sec. 12, T. 78, R. 1 W	770	158	Clay, 140 feet; silt and sand, 18 feet; rock at bottom.
F. D. Wood, sec. 27, T. 77, R. 3 W	750	208	Mainly blue clay with few pebbles; no rock struck.
A. Wiggam, sec. 10, T. 76, R. 3 W	750	170	Loess, 12 feet; yellow till, 38 feet; gravelly sand, 25 feet; blue till, 25 feet; yellow cemented gravel, 10 feet; very hard blue till, 60 feet; sand, 8 feet.
Sec. 30, T. 76, R. 3 W	720	154	Mainly till; gravel at bottom.
L. Eppelry, 3 miles north of Letts.	735	200	No rock entered.
A. Cone, sec. 24, T. 76, R. 4 W	660	200	Till, 130 feet; very hard till, 60 feet; sand at bottom, 10 feet.

In northern Louisa County, near Letts, several wells have obtained inflammable gas in sand below till at depths of 100 to 150 feet. These wells are situated just within (south of) the ridge marking the limits of the Illinoian drift, at a level perhaps 50 feet below its crest, or about 675 feet above tide. It is reported by the residents that beds of black muck and peaty material are found closely associated with this gas, and it is probable that the gas is derived from the decomposition of organic matter in these beds. The horizon seems rather low for the Yarmouth beds, unless the Kansan till sheet has been eroded. Prof. F. M. Witter, of Muscatine, Iowa, has presented a brief discussion of these wells in the American Geologist.[1]

The drift in the vicinity of Columbus Junction may exceed 300 feet in depth. A well made by Dr. Daniel Overhalt in the Iowa River Valley, near Columbus Junction, at a level about 130 feet below the uplands,

[1] Am. Geologist, May, 1892, pp. 319–321.

reached a depth of 164 feet without entering rock; the bottom of the well is estimated to be but 416 feet above tide. The following section of this well is reported by the well driller, L. Williams, of Columbus City:

Section in well in Iowa River Valley near Columbus Junction.

	Feet.
Alluvium	8
Blue pebbly clay	72
Sand	2
Blue clay	14
Sand	68
Total	164

Dr. Overhalt has a well on the bluff back of Columbus Junction at an altitude 130 feet above the well just noted, which reached a depth of 166 feet. It penetrates about 35 feet of loess and yellow till, beneath which it is mainly in a blue till to within 6 feet of the bottom, where sand and gravel are struck. It is probable that the blue till in this and the following two sections is Kansan. A well made for Hon. J. W. Garner at Columbus City penetrated only 13 feet of loess and yellow till, beneath which 157 feet of blue till was passed through before a water-bearing sand was found. L. Williams's well, in Columbus City, passed through 20 feet of loess and yellow till and then penetrated 108 feet of blue till before entering water-bearing sand. Within 2 miles west or south of Columbus City rock is found at depths of only 20 to 40 feet, and the drift is largely a yellow till.

Near Cairo, in Louisa County, Iowa, two wells on the crest of the outer ridge of the Illinoian drift sheet, at an altitude of about 750 feet above tide, reached a depth of 130 feet without encountering rock. They are mainly through till, much of which is probably Kansan. On the outer face of the ridge, near the base, at an elevation of 50 feet below the crest, a well was sunk by R. Cotter which enters rock at about 50 feet. Rock is also exposed in the bluff of Long Creek, north of Cairo, beneath about 60 feet of drift, mainly till.

Along the outer ridge of the Illinoian drift in northwestern Des Moines County several deep wells have been sunk, some of which penetrate a bed of peat or muck at about the level of the base of the ridge and the surface of the Kansan sheet of drift. It is here that the Yarmouth section given above (p. 42) is found.

In some places along the outer ridge of the Illinoian drift wells have

passed below the level of the outer border plain before entering the black muck which is thought to separate the Illinoian drift from the Kansan. In such cases the well is supposed to have struck into a valley which had been excavated in the earlier sheet of drift, though there is a bare possibility that an older soil horizon is struck. The following section of a well on the farm of F. Smith, about a mile south of Yarmouth, will illustrate the condition just mentioned:

Section in well on farm of F. Smith, a mile south of Yarmouth, Iowa.

	Feet.
Yellow till, becoming gray below (Illinoian)	36
Sand, with thin beds of blue clay and also of cemented gravel, probably in part Illinoian and in part alluvial	73
Black muck, containing wood (Yarmouth)	6
Sand and gravel, probably alluvial	8
Gray silt, apparently pebbleless, probably alluvial	15
Blue till (Kansan)	42
Depth	180

This well is on the crest of the ridge at a level 60 or 70 feet above the outer border plain. The black muck is therefore at a level about 40 feet below the plain. A well in the neighboring section on the south, at an elevation 25 feet lower, enters rock at a depth of 182 feet.

One of the thickest drift sections found along this drift border is in a well made by Anton Totemeir near New London, Iowa, in sec. 19, T. 71, R. 4 W., which struck rock at a depth of 276 feet. The section of the well indicates that only the upper 40 feet should be referred to the Illinoian drift sheet. The section as reported by Mr. Totemeir is as follows:

Section in well of Anton Totemeir, near New London, Iowa.

	Feet.
Pebbly yellow clay (Illinoian)	30
Pebbly blue clay (Illinoian)	10
Deeply stained, reddish-brown pebbly clay (Kansan)	12
Blue pebbly clay, with thin beds of sand, possibly including pre-Kansan as well as Kansan	224
Total	276

The well mouth being about 750 feet above tide, or 240 feet above the Mississippi River in Burlington, the rock floor at this well is but a little lower than the bed of the present Mississippi at Burlington. Of the several wells along this ridge in Des Moines County none have been found to enter rock at less than 120 feet, and probably at least half this drift is older than the Illinoian.

Along the ridge in southeastern Henry County, as in northwestern Des Moines County, wells not infrequently pass through a bed of muck or peat at the base of the Illinoian drift sheet. In a well made by Andrew Johnson, 1½ miles south of New London, there were logs and wood, occupying a space of nearly 4 feet, found at a depth of 40 to 45 feet from the surface. The writer obtained specimens of the wood and of peaty material associated with it, which await specific identification. Mr. Johnson reports the section of the well to be as follows:

Section in well of Andrew Johnson, 1½ miles south of New London, Iowa.

	Feet.
Yellow clay, without pebbles (loess)	6
Pebbly yellow clay (Illinoian)	20
Sand	3
Blue pebbly clay (Illinoian)	12
Peat and wood (Yarmouth)	4
Gray gummy clay, with few pebbles (Yarmouth)	10
Total	55

A well made by J. M. Lee, 3 miles northeast of New London, passed through a bed of black muck containing wood, just before entering rock, at a depth of 105 to 110 feet. This probably underlies the Kansan sheet of drift.

The drift of Lee County, as of counties to the north, belongs mainly to the sheet which underlies the Illinoian. Numerous exposures, and also well sections, show the Illinoian drift to have a thickness of but 20 to 30 feet on the plain east of the terminal ridge, and 30 to 70 feet on the ridge. The average thickness of the combined drift sheets in the county is probably at least 100 feet. On the borders of the Mississippi the thickness exceeds 300 feet, as shown by a well on the bluff north of Fort Madison and another at Mont Clare. The deposit of loess coating the Illinoian drift in this county has an average depth of only about 6 feet. Between the loess and the Illinoian drift there is a well-defined soil (Sangamon), usually of black color. At the top of the Illinoian drift there is often a mucky clay containing only fine pebbles, but the greater part is a stony till with occasional bowlders and numerous rock fragments 1 to 6 inches in diameter. As noted above, this sheet of drift is often so thoroughly leached from top to bottom that no response with acid can be obtained. Whether this feature is notably characteristic of the drift border for some distance to the north and south has not been determined.

Along the crest of the terminal ridge from Skunk River southward to West Point numerous wells have been sunk to a depth of 60 feet and a few to greater depth. They penetrate till the greater part of the depth, though in one instance the lower 50 feet is sand and gravel. The thickness of the drift ranges from about 80 to 120 feet or more. Of this the lower 40 or 50 feet is older than the Illinoian. Several of the wells have passed through peat, containing wood, at about the level of the base of the ridge, and there is an excellent exposure of a black muck below the Illinoian drift in a ravine about a mile northeast of West Point on the east slope of the ridge. At this exposure the following section is found:

Section in a ravine about a mile northeast of West Point, Iowa.

	Feet.
Yellow silt or loess (Iowan)	6
Soil, with ashy gray subsoil (Sangamon)	5
Brown till containing many bowlders (Illinoian)	15
Black mucky soil with gray subsoil (Yarmouth)	6
Brown clay with few pebbles (Kansan) exposed	15
Total	47

The deepest well section obtained on this ridge is at the residence of Andrew Foggy, sec. 16, T. 69, R. 5 W., and this differs from other well sections in that neighborhood in containing a large amount of sand in the lower part. From observations in a neighboring ravine and Mr. Foggy's statements concerning material penetrated in the well, the following section is prepared:

Section in well of Andrew Foggy, near West Point, Iowa.

	Feet.
Yellow silt or loess (Iowan)	6
Black soil with gray subsoil (Sangamon)	4
Yellow till (Illinoian)	20
Sand, affording weak vein of water (Illinoian)	6
Blue till (Illinoian)	33
Sand and peaty material, underlain by a fine gravelly sand (alluvial and Kansan)	50
Limestone	12
Depth	131

It is probable that the Illinoian drift extends to the peaty material at a depth of 70 feet, for the well stands upon probably the most elevated point on the ridge in this county, at a level nearly 70 feet above the outer border plain. A neighboring well in the same section, on the farm of F. Timpe, penetrated about 12 feet of loess-like silt and slightly pebbly yellow clay, at which depth a very calcareous, sandy, yellow till is entered. This

changes to a blue till within a few feet. A large amount of wood was in the blue till near the bottom of the well, at a depth of 25 to 30 feet. The wood, however, is incorporated in the till in the same manner as bowlders or pebbles, and does not indicate a soil horizon. The well apparently terminated in the Illinoian drift.

On the plain east of this ridge a black soil (Yarmouth), which separates the Illinoian sheet from the underlying drift, has been noted in wells at the following depths:

Depth to black soil (Yarmouth) in wells on the plain near Denmark, Iowa.

	Altitude A. T.	Depth.
	Feet.	*Feet.*
C. A. Flohrer, sec. 10, T. 69, R. 5 W	725	30–32
W. Hawkins, sec. 13, T. 69, R. 5 W	715	16–20
E. Newton, sec. 24, T. 69, R. 5 W	725	35–40
C. H. Burton estate, sec. 25, T. 69, R. 5 W	720	30–35
Thomas Saunderson, sec. 35, T. 69, R. 5 W	720	20–22
Benj. Krehbiel, sec. 36, T. 69, R. 5 W	720	35–40
Mr. Holstein, sec. 30, T. 69, R. 4 W	725	45–48
S. Van Tuyl estate, sec. 30, T. 69, R. 4 W	715	35–37
G. B. Brackett, Denmark	700	20–26
James Conaro, Denmark	700	19–24
William Blackinton, Denmark	700	26
Dr. William Sloat, Denmark	700	25
Public well, Denmark	700	20–30

The wells at Mr. Flohrer's and Mr. Hawkins's pass through several feet of ash-gray clay, apparently a subsoil, immediately below the black soil. Exposures on ravines in this part of the county sustain this interpretation of soil and subsoil. The Van Tuyl well has the following series of beds:

Section in well on S. Van Tuyl estate, near Denmark, Iowa.

	Feet.
Yellow silt or loess, slightly calcareous and containing a few small pebbles near base (Iowan)	7
Brownish-yellow clay, with few pebbles and but slightly calcareous (Illinoian)	10
Brownish-yellow till, pebbly and calcareous (Illinoian)	8
Blue clay, with few pebbles (Illinoian)	10
Black mucky soil, with wood (Yarmouth)	2
Brownish-yellow till (Kansan)	12
Hard blue till (Kansan)	6
Limestone	4
Total	59

The well at Dr. Sloat's penetrates the following beds:

Section in well of Dr. William Sloat, in Denmark, Iowa.

	Feet.
Yellow silt or loess (Iowan)	6
Brownish-yellow clay, slightly pebbly (Illinoian)	20
Mucky clay, largely of gray color and containing a few small pebbles (Yarmouth, and possibly Kansan)	15
Brownish-yellow till (Kansan)	10
Dark-blue till, with beds of sand yielding water	5
Total depth	56

The well at Mr. Conaro's was carefully observed by the writer during its excavation, and has the following section:

Section in well of James Conaro, in Denmark, Iowa.

	Feet.
Yellow silt or loess (Iowan)	9
Brown clay, not calcareous, with occasional pebbles, 3 inches or less in diameter (Illinoian)	10
Soil and grayish subsoil, slightly pebbly, not calcareous (Yarmouth)	5
Brownish-yellow till, leached for 6 feet at top, remainder very calcareous (Kansan)	25
Total depth	49

At Mr. Blackinton's well, which was also personally observed during its excavation, the upper 20 feet is a thoroughly leached clay; the remainder is calcareous till of brownish-yellow color, which includes thin beds or pockets of sand and extends to the rock, which is struck at a depth of 54 feet. In this connection it may be remarked that several of the wells in the vicinity of Denmark penetrate yellow till below the Illinoian drift sheet to a depth of 25 or 30 feet, there being little or no blue till above the rock. At the public well, however, a blue-black till occurs at 52 to 63 feet. Exposures on ravines both north and south of the village also have a dark blue-black till beneath the yellow at a level 15 or 20 feet below the top of the Kansan sheet of drift. Possibly this is pre-Kansan till.

On the bluff north of Fort Madison a well made at the residence of Mrs. Heitz reached a depth of 315 feet without entering rock. Blue till was entered at 27 feet, which, with the exception of a thin sand bed, presents a solid mass 260 feet in thickness. Beneath this till, in the lower 26 feet of the well, there is a cemented gravel. Exposures in neighboring ravines indicate that the Illinoian drift sheet on the bluffs at Fort Madison is not more than 20 feet in depth. The thick bed of blue till passed through in the well is apparently as old as the Kansan, and includes perhaps an earlier drift sheet. Along the Mississippi bluff above Fort Madison there

are exposures of drift 180 feet in height. The upper 50 or 60 feet consists of alternations of till with sand or gravel, and is referred mainly to the Kansan. The remaining 120 feet is a nearly solid mass of dark-blue till, which is, however, characterized by stony parts that give it the appearance of being interbedded with gravel and cobble. These bands of stony material are very nearly horizontal. It is not certain that this should be referred to the Kansan; possibly it is pre-Kansan. Many bowlders are accumulated along the base of this bluff. A strip covered with these bowlders, having a length of 8 rods and a width of 3 rods, was carefully examined. It included 107 bowlders, with an average diameter of about 3 feet. The largest three exceed 6 feet in diameter; the smallest included in the count were at least a foot in diameter. Upon classifying the bowlders it was found that red granite greatly predominates, there being 85 specimens. Of the gray or dark-colored granite only 6 were found. The greenstones are represented by 10 specimens. The two remaining specimens were limestone. About one-fourth of the bowlders were glaciated on the sides exposed to view; probably many others are glaciated on the under side. The proportion of red granite is exceptionally large for this region, though it is probable that at least half the bowlders are of this class. These bowlders are probably largely from the dark-blue till.

The artesian wells in the Mississippi Valley at Fort Madison enter rock at a level about 135 feet below low water in the Mississippi, or at about 365 feet above tide. The drift is mainly blue till, such as is exposed in the neighboring bluff. It is older than the Illinoian, and possibly is pre-Kansan. This blue till is covered to a depth of 10 to 40 feet by alluvial sand, which in places extends to near the level of the river bed.

The artesian well on the Mississippi bluff at Mont Clare, about 12 miles southwest of Fort Madison, penetrated 305 feet of drift. It is reported to be mainly through clay for a depth of 250 feet, beneath which there is sand extending to the rock. This well, it should be noted, stands just outside the limits of the Illinoian drift. The drift, therefore, like that at Fort Madison, belongs to an earlier sheet than the Illinoian.

The Illinoian drift probably extends to the western limits of the upland in Hancock County, Illinois, throughout the entire length of the county. The drift, however, can not be referred entirely to the Illinoian invasion, for there are southeastward-bearing striæ in the western part of this county,

which indicate that the earlier ice invasion, from the Iowa side, crossed the Mississippi into western Illinois. Instances of a soil between till sheets have also been found in this county, as in the counties of southeastern Iowa just discussed, and this soil is referred to the Yarmouth interglacial interval. The distance to which the Illinoian sheet overlapped the earlier one is not known. It is probable that the heavy deposits of drift found in central and southern Hancock County should be largely referred to the earlier invasion.

A well made by William McCuen on the east slope of the terminal ridge of the Illinoian drift, about 4 miles south of Hamilton, has the following section:

Section in well of William McCuen, about 4 miles south of Hamilton, Illinois.

	Feet.
Yellow silt or loess (Iowan)	12
Soil and gray subsoil grading downward into a pale till (Sangamon and Illinoian)	22
Blue till (probably Illinoian)	8
Peaty muck with wood (probably Yarmouth)	4
Pebbly clay of bluish color (probably Kansan)	28
Total depth	74

Mr. McCuen reports that other wells in the neighborhood have penetrated a similar buried peat. It seems probable that this peat is at the base of the Illinoian sheet, though it may possibly be interbedded with other deposits.

From near Carthage southward past Stillwell there is a filled valley whose position is revealed by the deep wells, the filling being so complete that there are no surface indications of the course. The artesian wells at Carthage penetrate 214 feet of drift, and several wells between Carthage and Stillwell reach a depth of nearly 200 feet without entering rock, and one a depth of 220 feet. A well at Owen's mill in Stillwell enters rock at 207 feet. As the surface elevation at these wells is nearly 200 feet above the Mississippi River, those which strike rock enter it at about river level. Probably the deepest part of this filled valley is cut to a much lower depth, for the rock floor of the preglacial Mississippi is 100 feet or more below the level of low water in the stream. In nearly all these deep wells the drift is mainly a blue till similar to that exposed in the Mississippi bluff near Fort Madison, and, like that near Fort Madison, is probably older than the Illinoian. In some wells the blue till is entered at a depth of only 20 to 25 feet, but in the majority it is struck at 35 to 40 feet.

On the portion of the Mississippi bluff above Hamilton the drift is only 20 or 30 feet in depth and is largely of sandy constitution. It seems probable that some modification of the glacial drift has resulted through drainage connected with the melting of the Illinois glacial lobe. The evidences of a delta-like filling at the lower end of the Des Moines rapids, near Warsaw, are discussed on another page.

In Adams County the Illinoian sheet has a series of ridges developed near the border. The outermost one lies but a short distance east of the Mississippi bluff, and is interrupted by wide gaps through which the streams find passage into the Mississippi. The inner ridges occupy a portion of the divide between the Illinois and Mississippi rivers in the central and southeastern part of the county. These ridges differ greatly in structure from point to point. The portion of the outer ridge north from Bear Creek is composed largely of ordinary brownish-yellow till, but throughout its continuation south of Bear Creek, from near Mendon southward past Eubanks, it contains a large amount of sand and gravel. The upper 30 or 40 feet, however, is often of clayey constitution, and this included, probably, the entire Illinoian sheet as it extends about to the level of the base of the ridge. In places the sand and gravel beneath this ridge is thought to be of preglacial age, and it seems not improbable that the portions which contain Canadian rocks or other erratics may be composed in large part of slightly modified preglacial material. The material thrown out from wells at Mendon was carefully examined and was found to be a quartz sand, of orange color, entirely free from calcareous material. But exposures of a similar sand near Eubanks were found to include occasional Canadian rocks in their upper portion, as if the sand had been worked upon by the ice sheet and redeposited, together with some of the material contained in the ice. Upon following this ridge southeastward to Mill Creek a change to till is found, and the valley of Mill Creek, at the point where the ridge crosses, is shown by wells to have been filled to a depth of 150 feet or more with a clayey deposit which from description appears to be till, there being numerous pebbles incorporated in it. A well made at the residence of Mrs. Ihrig, on the west bluff of Mill Creek, in sec. 15, T. 2 S., R. 8 W., reached a depth of 155 feet without encountering rock. It was mainly through clay, except a few feet of sand at the bottom. A well on the east bluff of the creek, in section 12 of the same township, is 200 feet in depth and is

thought to have entered rock only 40 feet; it also is reported to have been largely through clay.

On the elevated district near Payson wells penetrate alternations of clay and gravel to a depth of 60 feet or more. A well made by Mr. Barnard, 1 mile west of Payson, after penetrating 60 feet of clay and gravel, entered a red clay, apparently formed from the limestone which underlies that region. In some places the gravelly beds of the drift seem to rest directly upon undecayed rock surface.

A small drift ridge is traceable southeastward from the village of Newton (Adams post-office), on which wells have been sunk to a depth of 75 or 100 feet without entering rock. The town well at Newton is reported to be mainly through clay, with a few feet of gravel at bottom. A well at Mrs. Wittemeyer's, on the crest of the ridge, about a mile southeast of Newton, reached a depth of 82 feet and apparently passed through a buried soil between sheets of till. Exposures of a buried soil are to be seen near the level of the base of the ridge in the road leading south from Mrs. Wittemeyer's, in sec. 35, T. 2 S., R. 7 W., but at that place it is underlain by sandy gravel. The following is a section of the well as reported by the owner:

Section in well at Mrs. Wittemeyer's, a mile southeast of Newton, Adams County, Illinois.

	Feet.
Yellow clay without pebbles (Iowan)	10
Pebbly yellow clay (Illinoian)	30
Mucky gray clay (probably a Yarmouth soil)	7
Sandy and pebbly clay grading downward into sand (Kansan)	35
Total depth	82

On the plain northeast of this ridge, from the village of Burton eastward to Liberty, the ravines expose a yellowish gummy clay, containing few pebbles to a depth of 50 feet, which is referred to the Illinoian. There do not appear to be large pebbles or bowlders in such number as usually occur in the typical till.

Farther south, in the vicinity of Plainville and eastward from that village, the ravines expose a large amount of cherty gravel and cobble in the lower part of the drift, but the upper part, to a depth of 20 feet or more, is usually a clay containing but few pebbles. This phase of the drift, as noted below, extends across Pike County and characterizes the extreme border of the Illinoian sheet. It is probable that the chert is a residual product from the cherty limestones of that locality.

Along the divide between the Illinois and Mississippi rivers, from the southeast corner of the county northwestward to the vicinity of Liberty, there is a ridge made up in part of till and in part of sand and gravel. In the vicinity of Kingston (Fairweather post-office) wells along the crest of the ridge have reached a depth of 90 feet without entering rock. The ravines near this village expose an ash-gray soil (Sangamon) below the loess, and beneath this a brown gummy clay, slightly pebbly, with occasional bowlders, which is probably of Illinoian age. This clay is seldom more than 15 feet in depth, and is underlain by sand containing few pebbles. In the vicinity of Beverly the sand is absent and a blue till appears below the brown gummy clay. A well at J. Sykes's, about a half mile east of Beverly, is thought to have entered preglacial sand in its lower part. The well is an excavated one, 6 feet in diameter, and several wagon loads of the sand were thrown out on the dump, where excellent opportunity for comparing it with the glacial deposits was afforded. An examination of these deposits, supplemented by information furnished by Mr. Sykes, enables the writer to present the following section:

Section in well of J. Sykes, a half mile east of Beverly, Adams County, Illinois.

	Feet.
Loess and gummy brown clay with few pebbles	35
Gray sand	3
Blue till, very stony, with large bowlders and fragments of wood	27
Gray sand and gravel, calcareous	5
Orange-colored quartz sand, noncalcareous	14
Total depth	84

This well is located in an elevated part of the county, about 350 feet above the Mississippi River. A similar deposit of sand was found in a well in the village of Beverly at a depth of 55 to 75 feet, or very nearly the same elevation above tide as the well at Mr. Sykes's, the well mouth being on ground 15 or 20 feet lower than the Sykes well. The numerous ravines leading eastward from this ridge toward McKees Creek may afford exposures of the sand, but none were noted by the writer.

Along the portion of the Illinois-Mississippi divide between Liberty and Fowler the drift is very thick and its lower part is of peculiar constitution. Well drillers and several of the residents report that after a depth of about 30 feet is reached a blue-black clay, with sand partings and with much wood, is entered, which extends down nearly or quite to the limestone underlying

that region. The writer had opportunity to examine the material thrown out of a well at the residence of James Loveless, in sec. 34, T. 1 S., R. 7 W., and found it to be a blue-black silt, very calcareous, and containing only minute pebbles and sand grains. Several specimens of wood from this silt which were inspected by the writer also carried a coating of similar silts. Above the silt there is ordinary till, except a thin coating of loess at the surface and pockets or thin beds of sand or gravel or silty clay in the till. In Mr. Loveless's well the following section appears:

Section in well of James Loveless, between Liberty and Fowler, Adams County, Illinois.

	Feet.
Yellow silt or loess	6
Ashy soil and subsoil containing a few small pebbles	12
Calcareous yellow till	22
Gray gummy clay, resembling soil, noncalcareous	2
Calcareous yellow till	18
Blue-black silt, very calcareous	2
Total depth	62

At the county infirmary, in sec. 11 of the same township (T. 1 S., R. 7 W.), a well struck rock at a depth of 165 feet. The lower 100 feet of the drift is a blue silt apparently similar to that in Mr. Loveless's well. A shallower well at the infirmary obtained water in sand and gravel at a depth of 40 to 58 feet. A well on the farm of Mr. Henry, in sec. 3, within a mile of the infirmary, has a section similar to that of the deep infirmary well and entered rock at 160 feet.

Several of the wells in the village of Liberty penetrate a similar blue-black silt, entering it at about 60 feet and continuing in one case to a depth of 90 feet without entering rock. In the vicinity of this village, however, rock is occasionally entered at a depth of 50 feet or less, and only 2 miles east of the village and at a slightly higher elevation rock is struck at only 25 feet.

There is a low ridge leading from the village of Coatsburg eastward 5 or 6 miles on which the wells occasionally enter a blue-black silt similar to that found on the district just described. A well at the mill in Coatsburg is reported to be mainly through pebbly clay to a depth of 65 feet, beneath which there is a blue clay with sand partings and wood embedded, which was penetrated 30 feet without entering rock. A boring for coal a mile east of Coatsburg is discussed in the Geology of Illinois because of the occurrence of this blue-black material in the lower portion of the drift, which is

there considered a "post-Tertiary soil" older than the drift proper, and formed under very different conditions. The following is the section there published:

Section in a boring for coal, a mile east of Coatsburg, Adams County, Illinois.

	Feet.
Soil and yellow clay	6
Bluish-colored clay and gravel	45
Clay with large bowlders	40
Black soil	2½
Clay (stratified)	6
Very tough blue clay	20
Rock entered at	119

It seems not improbable that the silt under the till of central Adams County is attributable to ponded waters held in front of the Keewatin ice sheet in the Kansan stage, for that ice sheet apparently crossed the Mississippi into Illinois near Hannibal, Missouri, and covered the lower courses of its eastern tributaries.

In Pike County typical till has been seen at but few points. The several drift ridges which traverse the county are composed largely of clay and sand in which only a few small pebbles occur. There is, however, on the borders of Hadley Creek, in the northern part of the county and the adjacent portion of Adams County, considerable waterworn chert in the base of the drift. This chert is apparently a residuary product from the decay of cherty limestone in that region, but it was worked over to some extent by the ice sheet and its associated waters, and this has resulted in the introduction into the chert of occasional bowlders and smaller stones of distant derivation, as well as the wearing and rounding of the chert fragments. These chert beds are in places 10 or 15 feet thick. They usually present the appearance of gravel beds, there being very little clay present. Exposures were found, however, east and southeast of Baylis, on the west side of Bay Creek, in which a large amount of clay is mingled with the chert and other stony material. In the southwest part of the county, which appears to have been but slightly glaciated, if at all, the chert beds remain intact at the surface of the limestone. Quarries along the east bluff of the Mississippi afford good exposures.

A few well sections and hillside sections obtained in the vicinity of the drift border are here given to illustrate and make clearer the above statements.

Hillside exposures on the line of Pike and Adams counties, in R. 5 W., have a bed of cherty gravel with occasional Canadian rocks resting on the surface of the limestone, and covering it to a depth of 5 to 15 feet. Above this gravel there is usually 40 or 50 feet of clay containing very few pebbles. The deeper exposures show it to be of a gray color, but the surface portion is yellow. Capping this clay is a thin deposit of loess, separated in places from the clay by a gray or ashy (Sangamon) soil.

At the residence of A. Hill, 2 miles north of Baylis, on the crest of the main drift ridge, a freshly excavated well was found to have the following section:

Section in well of A. Hill, 2 miles north of Baylis, Pike County, Illinois.

	Feet.
Brown clay with few pebbles	25
Gray sand	10
Gray clay, nearly free from pebbles	33
Total depth	68

At Baylis an experimental boring for water reached a depth of 90 feet without entering rock or penetrating coarse material of any kind. The upper 30 feet consisted of yellow clay and the remainder of fine sand. This well is located on the crest of the main ridge, at an altitude about 400 feet above the Mississippi River. East and south from Baylis numerous exposures are found in which a pebbly brown clay underlies the loess at a depth of 8 or 10 feet.

In the northeast part of the county, in the vicinity of New Salem and Griggsville, and thence north to the county line, the wells and natural exposures reveal only a small amount of stony clay, the greater part of the drift being nearly pebbleless. Rock is often entered at 30 or 40 feet, or even less depth.

In the vicinity of Time the ravines expose a pebbleless clay, probably a phase of the loess, to a depth of 20 feet or more, beneath which there is a slightly pebbly brown clay. The village well at Time reached the bottom of this brown clay at a depth of 50 feet, and then penetrated 20 feet of blue clay resembling putty, and terminated at a depth of 70 feet without entering rock. At J. E. Dinsmore's farm, south of Time (sec. 26, T. 6 S., R. 3 W.), a well 60 feet in depth is largely through typical till, exposures of which are to be seen in neighboring ravines. Mr. Dinsmore made a well in sec. 23, in a ravine 30 or 40 feet below the level of the upland plain, which

penetrated 40 feet of nearly pebbleless brown clay, beneath which there is a black muck 5 or 6 feet in depth which rests upon a red clay, apparently a residuary product from the decay of limestone.

East of Bay Creek, in T. 6 S., R. 2 W., wells along the outer drift ridge frequently reach a depth of 50 feet, and occasionally 80 feet, without entering rock. From descriptions of the material, it is probable that ordinary till is penetrated, but no exposures were found. The loess in that locality is about 20 feet in depth.

From Pike County the drift border passes to the east side of the Illinois. A typical till constitutes the greater part of the drift exposed in ravines along that side of the river in Scott, Greene, and Jersey counties. The loess on the river bluff is usually 20 or 30 feet in depth, but within 8 or 10 miles east of the river it decreases to 10 feet or less. The drift forms a deposit probably 50 feet in average depth at the east border of the Illinois Valley, but immediately west of the Illinois, in southern Pike and in Calhoun County, there is scarcely a trace of drift.

There are several knolls and ridges of drift a few miles back from the drift border in Greene and Jersey counties, but no accurate well sections or other exposures of their structure were obtained. The descriptions given by residents, however, indicate that they are composed largely of clay.

In Madison County typical till is found along the east bluff of the Mississippi throughout the entire width of the county, as well as at points farther east. At the immediate border of the valley there is a deposit of loess 30 to 50 feet in depth, but within 10 miles back from the bluff the thickness decreases to 10 feet or less. The till is usually 25 to 50 feet in depth, and where thickest is of a blue color near the bottom.

Opposite Madison County, in St. Louis County, Missouri, north from the city of St. Louis, deposits of waterworn material of glacial derivation underlie the loess for a few miles back from the bluff of the river. These deposits contain a few bowlders, 1 to 2 feet in diameter, as well as cobble and gravel. The rock constituents appear to be different from those of the drift in Madison County, Illinois, there being present considerable material apparently brought down from the exposures of the sandstone and limestone of Silurian age on the borders of the Mississippi in Calhoun County, Illinois, and Lincoln County, Missouri. The presence of this material suggests water rather than ice transportation, and it remains an open question whether

the ice sheet reached into northern St. Louis County from the Illinois side of the river.

On the east bluff of the Mississippi below East St. Louis only a small amount of glacial drift has been found beneath the loess deposits, which there cap the bluff to a depth of 30 to 50 feet or more. The drift usually consists of a thin bed of stony material, but in some of the recesses of the bluffs and in ravines exposures of nearly pebbleless clay are occasionally seen. Some of these exposures near Columbia, in Monroe County, reach a depth of 40 to 50 feet. An occasional bowlder a foot or more in diameter is found in these deposits, but stones are very rare compared with their number in the typical till, such as is exposed in the east bluff of the Mississippi above East St. Louis. It is probable that the ice sheet extended as far west as the east bluff of the Mississippi in St. Clair, Monroe, and Randolph counties, but the deposits there are very much thinner than in drift ridges, discussed later, which traverse the eastern portion of these counties, and which perhaps mark an ice margin at a somewhat later period than that of the maximum extension.

The portion of the drift border in southern Illinois, on the slopes of the elevated rock ridge in Jackson, Williamson, and Saline counties, contains typical till, but the deposit is seldom more than 20 or 25 feet in depth. In one instance, however, a well in the southwest township of Williamson County was found to have reached a depth of 70 feet without entering rock. The distance to rock is also great in the vicinity of Murphysboro, in Jackson County. The wells and borings for coal often reach a depth of 100 feet, and occasionally 130 feet, before entering rock. The drift is reported to be largely sandy material, but the upper portion, exposed to a depth of 50 feet by Big Muddy River, is mainly clay containing but few pebbles.

On the borders of the Ohio Valley, in Gallatin County, Illinois, there is a belt of sandy material several miles in width which is not referred with certainty to glacial deposition. Back of this a typical till sets in, which is exposed in ravines beneath 8 or 10 feet of loess. Wells usually reach the bottom of the drift at 20 or 30 feet, but one 2½ miles north of Ridgway reached a depth of 98 feet without entering rock, and another 3 miles west of Ridgway a depth of 75 feet. In the Ohio Valley at Shawneetown a boring for gas and oil penetrated 112 feet of alluvial and other deposits

before entering rock This appears to be outside the glacial boundary, but the material penetrated is probably derived from glacial deposits brought down the valley.

In southwestern Indiana the drift in the vicinity of the glacial boundary frequently reaches a depth of more than 100 feet in the valleys; but on the uplands it rarely exceeds 40 feet, and is usually but 10 or 20 feet. As a rule, a deposit of till several feet in depth appears along the drift border, but in places there are only scattering pebbles for a mile or more back from it. The latter feature is most frequently found in the hilly parts of the border.

The till in the portion of southwestern Indiana south of East White River contains a remarkably small number of bowlders and coarse fragments of rock. In places search is necessary to discover a pebble, though in a neighboring exposure a large bowlder may be found. In a few localities sand is present instead of clay, but, like the clay, it carries very few pebbles. It is thought that these peculiar phases of the drift may be due in part to the character of the underlying rocks (there being a preponderence of friable strata which might easily be reduced to clay or sand) and in part to imperfection of drainage conditions, by which the very fine material was all retained in the till instead of being allowed to escape down the valleys, as in regions to the west, where drainage conditions were better. In connection with the first of these causes, it may be remarked that the local rocks throughout the entire region covered by this glacial lobe usually form so large a proportion of the coarse constituents of till that its character is found to vary in a pronounced degree in accordance with changes in the underlying rocks. The imperfection of drainage in southwestern Indiana attending the ice invasion was such that several lakes were formed in valleys which lie outside the drift border and whose streams had discharged westward before the ice invaded the territory covered by the ice sheet. These glacial lakes are discussed at some length on later pages, as are also the changes of drainage which resulted from the ice invasion. North from East White River the till usually carries a moderate number of pebbles, and differs but little from the typical till of the interior portion of the district covered by the Illinois lobe. The coarse rock fragments are composed largely of sandstone from formations which outcrop in the immediate vicinity of the drift border. Canadian rocks, however,

are well represented, and bowlders 4 feet in diameter are occasionally found on the immediate drift border.

Reference will be made to a few of the wells showing thick drift and to characteristic exposures, beginning in Posey County and passing northeastward.

The thickest drift noted in Posey County is in an abandoned valley which connects the head waters of Big Creek with Black River. One well in this valley, on the farm of Joseph Nesbit, about a mile west of Cynthiana, penetrated 127 feet of drift, and entered sandstone at that depth. The well mouth is only about 420 feet above tide and 80 feet above the neighboring portion of the Wabash River. The driller, T. F. O'Herron, of Haubstadt, reports that the entire depth is a stiff clay, of which the upper 36 feet has a brown or yellow color, and the remainder a blue color. On a neighboring farm, owned by Joseph Cale, a well reached a depth of 114 feet without entering rock. In this well two thin beds of fine gravel were passed through. Aside from these the drift is a stiff clay, of which the upper 40 feet is yellowish brown and the remainder a blue color.

On the head waters of Big Creek, in northwestern Vanderburg County, several wells 40 to 60 feet in depth do not reach rock. This valley appears to have been silted up to a depth of 50 feet or more in the portion immediately outside the glacial boundary. Wells there are reported to pass through "clay and quicksand."

In the vicinity of Haubstadt, within a mile north of the glacial boundary, there is a plain in which several wells have penetrated 40 to 70 feet of drift before entering rock. The upper 20 or 30 feet is yellowish-brown clay and the remainder blue clay. Occasionally the clay maintains a yellow color to a depth of 40 feet or more. The loess in that region, both outside and inside the glacial boundary, is about 12 feet in thickness and is similar in color to the oxidized portion of the underlying glacial drift.

In the ridged belt near Fort Branch there are several hillside exposures showing a few feet of till with considerable stony material just below the loess, and beneath this a fine sand. The wells along the ridge enter a soft blue clay, called "blue mud," at a depth of 30 or 40 feet. Only one well was found which entered rock. This is located at the residence of Lawrence Byers, near the east base of the ridge, and reached rock at a depth of 97 feet. Several wells along the crest of the ridge, 50 to 100 feet in depth,

do not enter rock. East of this ridge, along Sandy Fork of Pigeon Creek, wells are usually obtained at a depth of 25 feet or less. In some instances they penetrate alternations of blue clay and sand beneath the loess, while in other instances nothing but sand is found. In some of the ravines leading into Sandy Fork, a gray gummy clay carrying a few small pebbles immediately underlies the loess. It appears to be stained with humus, and probably represents the Sangamon interglacial stage. A creek exposure in the southwest part of sec. 23, T. 2 S., R. 10 W., shows a red, weather-stained, sandy gravel below the loess.

West of the drift ridge along Muddy Fork of Pigeon Creek, wells usually enter blue clay at about 30 feet, and in several instances have been sunk to a depth of about 100 feet without reaching rock. One well 3 miles west of Fort Branch, on the farm of Henry Lehring, struck rock at a depth of 114 feet. Two miles farther west, on more elevated ground, rock is struck at 12 to 20 feet.

In western Pike County, Indiana, in secs. 13, 23, 24, and 26, T. 1 S., R. 9 W., several roadside exposures of till having a thickness of 5 to 10 feet were found apparently at the extreme limits of glaciation. For several miles east from these sections the thickness of the drift on the uplands seldom exceeds 10 feet, and the loess here is reduced to a thickness of but 5 or 6 feet. In a lowland tract along Flat Creek, in eastern Pike County, which lies near the glacial boundary, the drift has a thickness of 75 to 120 feet or more. At the village of Otwell, which stands in this lowland, Dr. W. M. De Motte made a boring which reached a depth of 119 feet without striking rock, though the well mouth is only 485 feet above tide, and scarcely 85 feet above the neighboring portion of East White River. A boring made by William Bell near the head waters of Mud Creek and Flat Creek, 6 miles west of Otwell, reached rock at a depth of 78 feet, and several other wells within 2 miles north and east are reported by Mr. Bell to have reached rock at 75 to 80 feet. The drift in this lowland is reported to be largely a blue mud. There is, however, considerable sand just below the loess, exposures of which may be seen along the ravines and at roadsides. This lowland, as indicated on a later page, was apparently the line of discharge for a part of the Patoka drainage basin into White River, which it entered near the junction of the two forks east of Petersburg. On the uplands bordering this lowland on the north and east, rock is usually entered at 35 feet or less, while on the

uplands to the south it is found at 6 to 10 feet, there being little, if any, drift present.

As already noted, in northwestern Dubois County there is a low plain covering about 50 square miles in which the loess is underlain by sand. The sand appears to have been deposited in the glacial lake Patoka, formed by the obstruction of the Patoka River by the ice sheet, the preglacial course of the river having been northwestward across this plain into East White River. The plain was built up to a level of about 480 feet above tide, which has been increased to 485 to 490 feet by the subsequent loess deposit. The surface of the sand at the base of the loess is deeply weather-stained, showing that it long antedated the loess in deposition. On the borders of this plain, about 3 miles north of Jasper, in sec. 15, T. 1 S., R. 5 W., an exposure of black soil was found immediately below the loess, which was apparently formed in the Sangamon interglacial stage. The clay below it contains a few glacial pebbles.

In southeastern Daviess County, as noted above, the drift for a mile or two back from the glacial boundary is reduced to a few scattering pebbles. A heavy sheet of till there sets in, which fills the country to a nearly uniform level and produces plains known as "the flats," on which the drift ranges from 20 to 80 feet or more in depth. The plane surface extends nearly to the glacial boundary in the vicinity of Whitfield, Mount Pleasant, and Loogootee, in Martin County. There are, however, scattering pebbles on the hills along the east border of the plain. On a tributary of Boggs Creek, 2 miles north of Loogootee, exposures of till occur 30 feet or more in height, in one of which a granite bowlder 4 feet in diameter was noted. Along much of the boundary from Loogootee to Scotland the drift is very thin, though it apparently forms a nearly continuous sheet. There are low hills along the east border of Daviess County which for several miles inside the glacial boundary show only a thin coating of drift. But the lowlands in that region have apparently been filled to considerable depth.

At Scotland and along ravines northeastward there are exposures of sandy till 10 to 20 feet in depth at points within a mile of the apparent limits of glaciation. The hills in that region, however, carry very little drift.

In the lowland tract north of Plummer's Creek there are heavy deposits of sand, which in places are capped by a few feet of fine gravel, apparently a glacial deposit. The filling amounts to 75 or 100 feet, and seems excess-

ive when compared with the amount of drift on neighboring hills. On some of the hills between Rockwood and Park post-office, there is scarcely a trace of drift, though they are surrounded by the lowlands in which heavy deposits of drift occur. The drift continues thin on uplands as far north as Richland Creek, and the boundary is located with some difficulty.

From the narrows of Richland Creek, in secs. 8 and 9, T. 7 N., R. 4 W., northeastward to Newark, there is an exceptionally large amount of drift in the vicinity of the glacial boundary, both on uplands and on lowlands. Several exposures were found 200 feet above the creek, in which there is not less than 50 feet of drift. The old course of Richland Creek, through a lowland tract east of Newark, has been filled up to a height of nearly 100 feet above the creek with deposits of sandy clay, carrying a liberal admixture of coarse rock material and an occasional bowlder.

Siebenthal reports that in southeastern Owen County the drift is heavy in the valleys, but comparatively thin on the hills, and this feature is characteristic of the boundary in Monroe County and southern Morgan County, as noted both by Siebenthal and by the writer. Small bowlders are present in moderate number in the vicinity of the glacial boundary in all these counties.

CHARACTER OF THE OUTWASH.

There appears to have been very little material carried out by water beyond the edge of this ice sheet except along the valleys. While the outer border plains and the small valleys heading in this drift margin occasionally bear thin deposits of sand and fine gravel which seem to be an outwash from the ice margin, there is nothing comparable to what is displayed along some moraines of the Wisconsin stage described below.

The best exposure of such an outwash yet noted is found near West Point, in Lee County, Iowa. About a mile northwest of the village, immediately outside the Illinoian drift border, the following series of deposits is exposed in the gradings along an east-west road:

Section near West Point, Iowa, showing gravel outwash.

	Feet.
1. Brown silt, apparently to be classed with the Iowan loess	7
2. Fine gravel, considered an outwash from the Illinoian drift	1 to 2
3. Ash-colored soil, representing the Yarmouth interglacial stage	1½ to 2
4. Kansan till, brown at top, becoming a yellowish gray at bottom, exposed	15 to 20

The full extent of the gravelly outwash at this place is not known, because of the silt cover, but it seems to be restricted to a strip extending

scarcely one-half mile out from the margin of the Illinoian drift. The presence of the soil beneath this gravel makes it evident that there was but little erosion accompanying the deposition of the gravel. It also shows that the gravel is not a residue of coarse material formed in the process of erosion of the Kansan till sheet, either before or after the Illinoian glaciation.

The principal valley affording a line of drainage for the ice sheet was the Mississippi, only short sections of the eastern tributaries being outside the Illinoian drift margin. This valley was covered by the ice sheet, as already indicated, from near the south end of the Driftless Area down to the vicinity of Fort Madison, Iowa. Possibly also it was encroached upon for a few miles in the vicinity of St. Louis, Missouri. The blockade in the portion bordering eastern Iowa was so complete as to cause the opening of a temporary line of drainage across eastern Iowa outside the ice margin, as indicated below; but there appears to have been at most only a partial blockade near St. Louis. An examination into the character of the deposits in the Mississippi Valley, between Fort Madison and St. Louis, has brought to light nothing to indicate vigorous drainage at the Illinoian stage of glaciation. Indeed, the valley seems to have become filled to some extent by sand and finer material at places where, previous to this glaciation, erosion had been in progress. This is markedly the case just below the lower rapids. The filling there is mainly silt and fine sand, though a fine gravel appears in places where the current was strongest. This matter is discussed more fully below (pp. 94–96). In the section of the Mississippi also between St. Louis and Cairo only sand and silt are found along the valley, a feature that apparently indicates a drainage no more vigorous than at the present day. Yet it seems probable that at times the volume of water greatly exceeded that now discharged through the valley.

Much remains to be learned concerning the drainage conditions attending this and later stages of glaciation, but from what is now known the drainage at the Illinoian stage appears to have been very sluggish not only on the Mississippi, but on all the valleys leading away from the ice sheet.

THE RIDGED DRIFT OF THE KASKASKIA BASIN.

The position of the principal ridges in this system may be seen by reference to the glacial map (Pl. VI). It will be observed that there is one belt lying near the Kaskaskia River and found chiefly on its west border.

Another belt a few miles to the west runs nearly parallel to the river from Tower Hill, in Shelby County, southwestward to Belleville, in St. Clair County. Still farther west there is a system, less definitely developed, leading from northern Montgomery County southward into northeastern Madison County. South from Belleville the ridges are reduced to a single chain which follows the west border of the Kaskaskia from Lementon, in St. Clair County, southward across eastern Monroe into northern Randolph County. The ridge there crosses to the east side of the river and passes southeastward near Sparta to Steelville. There is a slight ridging as far southeast as central Jackson County, beyond which the drift appears not to be definitely ridged. There are, however, occasional low ridges and swells in the vicinity of the glacial boundary in Williamson, Saline, and Gallatin counties, which may mark the continuation of the belt.

Of the three systems developed northeast of Belleville the middle one is the best defined and most nearly continuous. It is interrupted only by a few narrow gaps, usually less than 2 miles in width, throughout the entire distance from Tower Hill to Belleville, nearly 100 miles. There are places, as in northeastern Montgomery and in southeastern Madison County, where a continuous ridge is maintained for a distance of at least 15 miles. The belt bordering the Kaskaskia River is maintained for several miles as a continuous ridge in the vicinity of Vandalia, but elsewhere is represented only by fragmentary ridges, seldom more than 3 miles in length, between which there may be gaps of even greater length. The western of the three belts is even more fragmentary, and is maintained for only 20 or 25 miles.

These ridges are usually rather sharp and narrow, but in places assume a billowy topography. In still other places they have a vague irregularity of form and arrangement. The more sharply ridged type, however, prevails over the others, and may be said to characterize the system. The sharpest ridge noted is that in the vicinity of Cool Spring post-office, in Shelby County, where a ridge scarcely a mile in width has a height of 130 feet. A long ridge leading from Pocahontas, in Bond County, westward into Madison County, and thence southward to the village of Highland, is about 50 feet in average height and scarcely a half mile in average width. Knolls 75 or 100 feet in height are not rare, and occur in nearly every county traversed by this system of ridges. These knolls, as well as the

ridges, often rise abruptly from very flat tracts, and seldom shade into the bordering plain, a feature which distinguishes them from the moraines of the Wisconsin series, which usually grade into plane tracts on their inner border.

The ridge leading southeastward from the Kaskaskia across northeastern Randolph and western Jackson counties is not so sharp as the majority of ridges west of the Kaskaskia, and has a gently undulating surface, similar to that of the ridges formed on the drift border in western Illinois and southeastern Iowa. It seems, however, to be definitely connected with the system of ridges following the west side of the Kaskaskia, and can scarcely be included with the ridges which characterize the drift border.

The entire system of ridges is composed largely of typical till, blue till being present in the lower portions and brown till near the surface. In a few cases gravel and sand have been found, but such material is so rare that railways have not found it expedient to obtain ballast from these ridges.

The origin or mode of formation of these ridges is problematical. Their trend is nearly in line with the ice movement, as shown by striæ in the neighborhood of Alton, in Madison County, and is about at right angles with the course of the boundary of the Illinoian drift sheet. Several working hypotheses were employed during the field investigations, among which may be mentioned the following: (1) That the ridges are similar in origin to drumlins. (2) That the ridges constitute an interlobate morainic system formed in a reentrant between a supposable lobe which covered western Illinois and one which covered southern Illinois and southwestern Indiana. (3) That the ridges mark the western border of a lobe which persisted in southern Illinois after the ice had retreated from western Illinois. (4) That the ridges are dependent in some way upon obstructing rock hills which constitute their nuclei. (5) That the ridges are a remnant of a sheet of drift which once filled that region to the height of their crests.

In the study of these ridges it was found that in a few instances they bear resemblance to drumlins in their form, but the great majority bear little or no likeness to that class of ridges. The hypothesis of an origin similar to drumlins is therefore held somewhat lightly, but is not rejected.

The hypothesis that these ridges were formed as an interlobate belt

lacks support because of the absence of a system of ridges leading up from the west. It is perhaps opposed by the direction of the neighboring striæ at Alton, which is southwestward, parallel with the ridges, instead of southeastward toward them. This hypothesis, therefore, is held lightly, but is not rejected.

The hypothesis that this system of ridges marks the western border of a lobe which persisted in southern Illinois after the withdrawal of the ice from western Illinois is apparently supported by the distribution of the ridges. This is especially true of the southeastward extension of the belt across Randolph and Jackson counties which, in a measure, encircles the supposed lobe. This hypothesis apparently is the best-supported one of the group.

The hypothesis that rock hills may constitute nuclei for the ridges was suggested by the occurrence of such hills in western Shelby County, in the midst of the system of ridges, but no evidence was found elsewhere along the belt which would support this view. Indeed, the majority of ridges have such abruptness that they can scarcely be supposed to carry an equally abrupt ridge of rock. The formations in that region are largely shale or shaly sandstone which, in all probability, would be preserved only in low hills and ridges with gentle slope.

The hypothesis that the ridges are remnants of a sheet of drift which once covered this region to the height of their crests is presented in the Illinois Geological Reports as an explanation for their occurrence. This hypothesis involves such a vast amount of erosion as to be entirely unsupported by the features of the region, and is therefore no longer considered applicable.

BUFFALO HART MORAINE.

The Buffalo Hart moraine is well defined for a distance of about 15 miles in eastern Sangamon and southwestern Logan counties, passing from the Sangamon River near Mount Auburn northwestward past Buffalo and Buffalo Hart to Elkhart. It consists of knolls of considerable prominence, somewhat closely aggregated, many of which are 30 or 40 feet and a few 75 or 80 feet or more in height. Among the knolls there are sloughs and shallow basins, giving the surface a subdued type of knob-and-basin topog-

raphy. This belt has an average width of nearly 2 miles. East from it there are scattering knolls of considerable prominence, one at the town of Mount Pulaski being nearly 30 feet in height.

The connections of this belt with other moraines are rather vague. There is, however, toward the southeast, a series of mounds and short ridges occupying the interval between the southern end of this moraine and the northern end of the ridged drift of the Kaskaskia Basin. In case those ridges prove to have been formed by an ice sheet occupying the district east of them, the Buffalo Hart moraine would seem to be a natural northward continuation of the belt.

The northern terminus of the Buffalo Hart moraine is in the form of a very prominent mound, rising 150 feet above the bordering country, or about twice as high as any of the other knolls in the moraine. It is known as Elkhart Mound, being situated about a mile east of the village of Elkhart, and has been a landmark from the early days of settlement. It commands a view for 20 miles or more in all directions. From this mound a low ridge leads off westward about 3 miles, where it merges into the general upland plain. There are two lines of possible continuation for this moraine. The eastern line would lead northward through western Logan and eastern Mason counties and embrace a series of knolls scattered over that region. The western line would follow the low ridge westward and cross the Illinois River near the mouth of Sangamon River and there connect with the small drift ridge mentioned above which occupies southern and western Fulton County. The features are too vague to make a satisfactory correlation along either line. It seems preferable, therefore, to leave the belt without an attempt at definite correlations.

The drift in this moraine, like that in the bordering plain, consists mainly of till. Even the very prominent Elkhart Mound has till exposed where the road crosses its northern slope. There are, however, local developments of gravelly material in some of the knolls and ridges, as in the Kaskaskia system of ridges. The moraine is covered with loess, usually to a depth of 12 or 15 feet, and this obscures greatly the underlying drift and renders it difficult to discover places where gravel may be obtained.

The knolls scattered over southern and western Logan County have been found in some cases to contain considerable sand, but they also, like the knolls of the moraine, appear to be composed principally of till.

The low drift ridge of southern and western Fulton County consists of till in its smoothest portions, but there are a few knolls in the northwest part of Fulton County which are of gravelly constitution. In this connection it may be remarked that the sections of wells made on knolls in western Illinois so far as obtained exhibit as a rule much more till than sand or gravel. In short, it may be said that the ridged drift and knolls of the Illinoian sheet are generally composed mainly of till and differ but little from the drift of the plane tracts which border them. But in northwestern Illinois the ridges of the sheet tentatively referred to the Illinoian are largely of gravelly structure and some are of esker type.

ESKERS OR GRAVELLY RIDGES OF NORTHWESTERN ILLINOIS.

Leaf River or Adeline esker.—The largest and best-defined esker found in northwestern Illinois stands in the valley of Leaf River in northern Ogle County, and is discussed by Hon. James Shaw in the report on Ogle County.[1]

It has been discussed more recently by Mr. Oscar Hershey, who has applied to it the name Adeline, from the village of Adeline, situated near its eastern end.[2]

As Judge Shaw's report was prepared before the distinguishing characteristics of eskers were fully known, the name moraine was very naturally applied to the ridge. This reference of the ridge to glacial action is of interest, since Shaw had, prior to the examination of it, followed the State geologist, Professor Worthen, in the support of the iceberg hypothesis as an adequate explanation for the drift phenomena of northwestern Illinois. Chamberlin was apparently the first to recognize this ridge as an esker, on a visit made to it about 1881, in his studies preparatory to the writing of the paper in the Third Annual Report.[3] The writer's examinations were made in the spring of 1886.

The esker, as may be seen by reference to Pl. XII, is a practically continuous ridge about 12 miles in length, extending from a point 1 mile east of Adeline westward to sec. 14, T. 25, R. 7 E., about 5 miles northwest from Forreston. The only notable gap occurs where a branch of Leaf River

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[1] Geol. of Illinois, Vol. V, 1873, pp. 108–109.

[2] Am. Geol., Vol. XIX, 1897, pp. 200, 201.

[3] Preliminary paper on the terminal moraine of the second Glacial epoch, by T. C. Chamberlin: Third Ann. Rept. U. S. Geol. Survey, 1883, pp. 291–402.

breaks through the ridge, 2 miles west of Adeline. The crest line is very uneven and the height of the ridge varies greatly. The highest points slightly exceed 100 feet above the plain bordering Leaf River, but their elevation is no greater than that of the uplands on either side of Leaf River Valley. The lowest points are scarcely 20 feet in height. The esker consists usually of but a single ridge, ranging in breadth from 100 feet or less to probably 1,000 feet. At its eastern end, in the vicinity of Adeline, there is a series of nearly parallel ridges and hillocks covering a breadth of perhaps one-half mile and almost filling the valley. At the western end of the ridge there is no delta, or fan-shaped gravel deposit, such as sometimes occurs at the terminus of an esker. There are a few small gravel knolls within a mile north from its terminus, but they do not appear to be definitely connected with it.

Several extensive excavations have been made in the esker, some of which expose its structure from top to bottom. It is made up largely of coarse gravel well rounded, but contains also beds of fine gravel and sand. The coarser material is most abundant in the upper portion and it is not rare to find bowlderets, and even moderate-sized bowlders, embedded in it. The lower portion displays much cross bedding. The direction of flow of the stream which formed this esker is clearly shown to be toward the west, or the reverse of the present drainage of the Leaf River Valley. As the esker now stands, its western end is nearly 100 feet higher than its eastern. In case the esker was formed under the ice in the valley which it occupies, considerable hydrostatic pressure would have been required to force the water, with its burden of gravel, up this slope. It does not, however, seem necessary to restrict the formation of the esker to the under surface of the ice sheet, since it is found that nearly stagnant ice is traversed by tunnels at some distance above its base.[1] The greater part of the gravel is composed of limestone such as occurs in the neighboring ledges, but there is also a liberal admixture of rocks of distant derivation. In order to compare the rock constituents of the esker with those of the till of the adjacent districts, pebbles were taken, without attempt at selection, from the esker and from a dump at the mouth of a well at Forreston, which

[1] See I. C. Russell, Jour. Geol., April-May, 1893, Vol. I, No. 3, pp. 240–242. See also Hershey's discussion in Am. Geologist, April, 1897, pp. 238–239.

had just been excavated in till. Upon classifying the rocks the following results were obtained:

Pebbles classified from an esker and the till near Forreston, Illinois.

	Esker.	Till.
Granite	6	4
Dark-colored basic eruptives	6	5
Red quartz-porphyry	1	0
Quartzite	1	0
Quartz	1	2
Siliceous shale and thin-bedded sandstone	0	6
Brown chert	8	3
White chert	21	21
Yellow limestone, largely Galena	86	76
Blue and gray limestone (Lockport and Trenton)	56	59
Total	180	176

Several fossils were found in pebbles of Lockport limestone, and also characteristic fossils of the Trenton and Galena, both by the writer and by other persons who have discussed this ridge. As the latter formations have an outcrop for only 40 or 50 miles to the east, the material may confidently be considered of local or semilocal derivation.

Hazelhurst esker.—A short esker is found near Hazelhurst, at the borders of Ogle and Carroll counties. (See Pl. XII.) The esker proper is a sharp ridge about 1½ miles in length, rising just west of Hazelhurst to a height of fully 100 feet above the station and maintaining a height of 60 to 75 feet for a distance of nearly a mile. Its eastern end is about a half a mile east of the village, and the western end about a mile northwest. The ridge is practically continuous, but has a slight deflection in its middle portion, one ridge terminating and another beginning a short distance south and immediately opposite the end of the former. The general trend of the esker is east to west, but the western end points northwest. There is no delta-shaped deposit of gravel at the western end. On the contrary, the ridge contains considerable till at that terminus. Several gravel pits have been made in the ridge near its eastern end, which show it to be composed, like that of the esker in Leaf River Valley, of very coarse material at the top and finer material in the basal portion. The pebbles are mainly limestone of local or semilocal derivation, as in the esker just discussed.

This esker is situated at the eastern edge of a basin formed in the Hudson River shales, which is drained by Elkhorn Creek and is known as the Elkhorn Basin. The neighboring districts on the northeast reach an elevation nearly as high as the crest of the esker. A well made on the slope of the esker a short distance west of Hazelhurst shows that the drift at that point extends nearly 100 feet below the base of the ridge and is composed entirely of sand and gravel, but at the village of Hazelhurst rock is reported to be struck in wells at a depth of only 20 feet.

There are several prominent gravel knolls in the immediate vicinity of the Hazelhurst esker, two of which reach a height of about 100 feet, the others being 20 to 40 feet high. They are situated immediately south of the esker, and are scattered over a width of a mile or more and a length from east to west of more than 2 miles. These knolls are slightly elongated in an east-west direction in several cases, but the two prominent ones are nearly conical. It seems probable that they were formed by agencies similar to those which produced the esker—i. e., by glacial drainage—and they are referred to the same esker system.

Garden Plain esker.—In western Whiteside County there is a small esker setting in immediately west of the village of Garden Plain, and passing thence westward through the north part of secs. 22 and 21, and terminating on the Mississippi bluff in sec. 20, Garden Plain township. It lies along the south side of the wagon road which leads west from Garden Plain, and in its entire length of 2½ miles does not vary 20 rods from a direct east-west line. The ridge has usually a height of but 5 or 10 feet and a breadth of 20 rods or less. Its structure is exposed only at one place, at a gravel pit in the west part of sec. 22. The beds here bear clear evidence of a westward-flowing stream. The gravel has remarkably fresh appearance, being stained but little more than the usual stain of the Wisconsin eskers, and much less than the stain presented by the gravels in the Hazelhurst and Leaf River eskers. It is barely possible that it was formed at the Iowan stage of glaciation, though, as shown below, evidence of the presence of the Iowan ice sheet in this region is far from decisive. The direction of flow of the stream which formed the esker being westward, the ridge can scarcely be referred to a movement of the waters from the lobe of Iowan ice which covered the district to the west of the Mississippi, even if that ice lobe crossed into Illinois. It would seem, therefore, that the esker must be referred either to the

Illinoian invasion or to an extension of the Iowan ice westward from the Rock River Basin.

Pecatonica esker system.—In Stephenson County there are several gravelly belts which have been studied in considerable detail by Mr. Oscar Hershey and are discussed by him in a recent paper in the American Geologist.[1] These gravelly belts bear less resemblance to typical eskers than the Adeline and Hazelhurst ridges. They are marked by frequent interruptions and display a series of branches or spurs which give them greater complexity than the ridges just discussed. The main belt follows the Pecatonica Valley from eastern Stephenson County westward to the mouth of Yellow Creek, about 3 miles east of Freeport; thence it passes up the south side of Yellow Creek to the village of Bolton. The length of this belt is nearly 20 miles, and the ridges are in places scattered over a width of 2 or 3 miles. Their distribution may be seen on Pl. XII. It will be noted that there are usually two, and in places several, parallel ridges traceable for a few miles; they then either diverge to form branch belts or die out altogether. Hershey has called attention to points of special development in these belts where the aggregate bulk of the ridges is increased to several times the usual amount. One of these points of special development occurs opposite the mouth of Yellow Creek, another 3 or 4 miles farther west, and a third at the western end of the belt at Bolton. These are interpreted by Hershey to have been formed successively from west to east, and to mark each the position of the ice margin at the time it was forming. The ingenious hypothesis which Hershey has presented may perhaps satisfactorily account for the development of these belts, but the question can scarcely be decided in the present state of knowledge of such phenomena.

At the western end of this gravelly belt the ridges culminate in an accumulation of greater strength than is displayed at any other point along the belt. An area of more than a square mile is occupied by sharp ridges, the highest of which rise 75 or 100 feet above the adjoining plain. The plain immediately west of this system of ridges, though imperfectly exposed to view, is apparently underlain extensively by sand, and is referred to by Hershey as a sand plain. It bears only slight resemblance to the deltas formed at the terminus of eskers in other localities, for the ridges do not merge into the sandy plain. As suggested by Hershey, there was probably

[1] Am. Geologist, Vol. XIX, 1897, pp. 197-209, 237-253.

a lake in the portion of the Pecatonica Basin west from the ice margin, for this basin is open only to the east, and in all probability a lake would occupy it outside the edge of the ice sheet and become expanded eastward with the retreat of the ice.

So far as examined, nothing was found either by Hershey or by the writer to indicate that the structure of this belt of ridges differs from that commonly displayed by eskers. In several of the ridges the upper portion is found to consist of a coarse gravel and cobble, but there are other ridges composed largely of sand and fine gravel. The pebbles are chiefly limestone, and are largely of local derivation. Hershey maintains that they are derived by direct wear from the neighboring ledges rather than as a residue from the till, but the writer is inclined to question this interpretation, since the structure of the till and of the eskers is, so far as he has examined in this district as well as elsewhere, quite similar in the kind of coarse rock ingredients.

Cedarville belt.—Hershey has traced two other lines of gravelly drift for several miles in an east-west course in the portion of Stephenson County north of the belt just discussed. To these he has given the names Cedarville and Orangeville. The former belt he considers to have its beginning in the valley of Rock Run, about 1½ miles east of Rock City, but it can not be definitely traced until it reaches the valley of Cedar Creek, about 2 miles above Cedarville. It is prominently developed southeast of Cedarville, where it rises into sharp knolls 80 or 90 feet in height, which have so obstructed the old valley of Cedar Creek as to compel the stream to cut a gorge on the north side of the village. The belt is again prominent near the junction of Cedar and Richland creeks, 2 miles west of Cedarville. It is again prominent at the village of Damascus. The belt extends about 3 miles farther in a northwestward course, as a line of sharp knolls, the terminus being about 3 miles northeast of the village of Lena. The well-defined portion of this belt is about 12 miles in length, but if we consider its beginning to be at Rock Run, its length is nearly 20 miles.

Orangeville belt.—The Orangeville belt has been only partially mapped by Hershey, and is found to be best developed south of the village of Orangeville, and again just north of Winslow. At the latter point it rises into a very prominent knoll with a number of associated ridges.

General observations.—The following observations concerning the belts in Stephenson and Ogle counties are made by Hershey, in the paper above cited:

(1) They are not confined to any level, but cross ridges of any height, in several cases 150 feet or more above the present bottom of adjoining valleys. However, they are best developed at lower levels and the most prominent knolls and ridges stand in the center of valleys.

(2) They will not bend from a direct course upon encountering a low ridge, but are readily compelled to change direction upon meeting one of the high ridges, which constitute the remains of the peneplain.

(3) When in a narrow valley there is usually but a single ridge and only few secondary belts, but in such a wide basin as that of the Pecatonica River and Yellow Creek, there are a number of parallel ridges.[1]

The system of eskers of northwestern Illinois indicate that the drainage from the ice sheet was somewhat vigorous, though the combined bulk of the gravelly material contained in them is but a small portion of the drift of that region. It is probable that they were formed during the general recession of a nearly stagnant sheet of ice. The trend of the main ridges is about in line with the supposed direction of the ice movement, which is usually nearly at right angles with the ice margin. Some of the ridges, especially the Cedarville belt and the Hazelhurst esker, curve toward the boundary in the western portions, changing from a westward to a northwestward course. Whether the ice movement was characterized by a corresponding curve can scarcely be determined, though it seems a not improbable movement.

TRANSPORTED ROCK LEDGES.

In northwestern Illinois there are several remarkable instances of transportation of limestone ledges which have been discovered by Hershey,[2] the most of which are indicated on Pl. XII. These ledges in some instances occupy an area of several acres. They have been moved westward from the crest of rock ridges without completely destroying their stratification. In most cases they have been deposited at levels lower than the ridges from which they are derived and rest upon glacial deposits on the slopes or bottom of neighboring valleys, but in some instances such ledges have been transported to points as high as their original position. It

[1] Am. Geologist, Vol. XIX, 1897, pp. 197–209, 237–253.

[2] Loc. cit., pp. 245 253.

seems necessary to call in the action of the ice sheet to account for these transportations, for they can not, as a rule, be the result of landslides or of a slow creeping down the slope. Hershey refers them to the closing stage of the ice movement, for the reason that if transportation had occurred in the midst of the invasion the ledges would, in all probability, have been more thoroughly intermingled with the drift. Except in a very few instances no drift pebbles have been found in the body of these deposits. There are often bowlders and smaller drift pebbles scattered over their surface.

Hershey has also discovered places where the ledges have been pressed into slight folds without suffering transportation. In these folds the strata show dips of 10 to 30 degrees, while the greatest dips of the strata due to orographic bending, so far as he has discovered, do not exceed 2 degrees The reference of this disturbance to ice action appears well sustained. If the folding of the strata is not due to this agency it seems necessary to refer it to a remarkable local disturbance, since the strata in the surrounding districts are practically horizontal.

The transported and disturbed rock masses are especially numerous in the township of Dakota, in Stephenson County. Within 4 miles west and southwest of the village of Dakota, Hershey has found at least thirty distinct deposits of this class. They are generally conical or dome-shaped masses a few rods in diameter, which appear as though embossed on the top and slope of high rock ridges. When the internal structure is revealed by excavations, the incoherent portions are found to alternate, both horizontally and vertically, with other portions in which the original bedding planes have been but little disturbed. Hershey cites two instances of the occurrence of transported ledges in the midst of valleys 2 or 3 miles west of Dakota, in which burrowing animals have brought out waterworn gravel and sand from under the limestone. The largest ridge is about 75 feet high and nearly obstructs the valley in which it stands. The smaller one is about 30 feet high and is composed of Galena limestone, not much broken, but with the strata dipping steeply in every direction from the center and top of the mound. These masses are scattered widely over Stephenson County east of the meridian of Freeport.

Hershey has noted a tendency to greater development of this peculiar class of rock transportation along lines leading north and south from the

strongly developed portions of the Pecatonica esker belt, and this has led him to suggest that along the lines where these deposits are heavily developed there is the culminating limit of some stage of glacial readvance—a suggestion which implies that the ice had not reached an entirely stagnant condition at the time the eskers were forming. The reader will find in Hershey's discussion of these ridges a detailed account of the several instances of transported rock ledges which he has examined, together with a discussion of their probable mode of origin. So far as known to the writer, such remarkable transportation of rock ledges has not been reported in other localities. Possibly the disturbed beds which pass horizontally into and rest upon undisturbed beds, have been wrinkled in post-glacial time in the manner suggested by Gilbert for the somewhat similar phenomena in New York, and which find illustration also in northeastern Ohio.[1]

GLACIAL STRIÆ.

Striæ have been found not only in the interior portion of the district covered by the Illinois lobe but also in several instances near the extreme borders. The latter usually bear directly toward the drift border. Thus in western Illinois the bearing is westward, in southwestern Illinois southwestward, in southern Illinois southward, and in western Indiana southeastward, as appears on the glacial map, Pl. VI. The striæ in southeastern Iowa present an apparent exception, there being several eastward and but one westward bearing observed. But it should be remembered that that district was covered prior to the Illinoian invasion by another ice lobe which deployed eastward across southeastern Iowa, and it is to that ice lobe that the eastward-bearing striæ are referred.

There are wide areas in this region where striæ have not been discovered. The absence of observations does not imply that the ledges are not striated, for too little attention has been given the rock surfaces to insure a complete mapping. It is probable that many more instances will be reported as detailed investigations are carried on. There are, however, extensive areas in which no rock exposures occur, and other areas in which the surface rocks are of such character as to break down quickly upon exposure, so that striæ can scarcely be preserved. This condition is found

[1] Proc. Am. Assoc. Adv. Sci., Vol. XXXV, 1886, p. 227. Also Vol. XL, 1891, pp. 249, 250. (See also Bull. Geol. Soc. Amer., Vol. X, 1899, pp. 131-134.)

not only in the sandy shales of the Coal Measures but also in a large part of the area immediately underlain by limestone. The Galena limestone, for example, has scarcely ever afforded exposures of striation in its extensive outcrops in Stephenson, Jo Daviess, Ogle, and Carroll counties, for its surface is usually so rotten, even under the deepest deposits of till, that striæ would not be preserved.

In not a few instances the ice sheet is found to have failed to remove the residuary clays which overlie the bed rock, and in such instances striæ, of course, were never formed. How extensively the surface ledges escaped striation is not known, but the present knowledge of rock exposures within the glaciated portion of the Mississippi Basin leads the writer to think that a large percentage of the rock surface never was striated.

A few of the striæ on the border of the lobe merit special notice. At the city of Burlington, Iowa, striæ formed both by the Illinois glacial lobe and by the southern extension of the Keewatin ice sheet are present. Only one instance, however, has been found in which the striæ on the Iowa side are certainly referable to the Illinoian ice sheet. This exposure occurs at the northeast corner of the intersection of Court and Prospect streets, in the north part of Burlington, and was the joint discovery of Mr. F. M. Fultz and the writer. The bearing is S. 72° W., and satisfactory evidence is found, from prominences on the striated ledge, that the movement was westward and not eastward. Striæ were discovered by the writer on the east bluff of the Mississippi, opposite Burlington, which have a nearly due east-west bearing. In this exposure the evidence concerning the direction of movement, whether eastward or westward, is not decisive, there being no prominences on the ledge which would throw light on the direction of movement. The bearing harmonizes more easily with a westward movement than an eastward movement, and the balance of probabilities seem in favor of westward movement.

The striæ due to the earlier or Keewatin ice lobe, both in Burlington and at other points north of the city reported by Mr. Fultz, have a bearing generally about S. 65°–70° E., their direction being about the same as that of striæ found by the writer near Washington, Iowa, and by Professor Calvin in the vicinity of Iowa City. One locality, however, was found in quarries one-half mile north of West Burlington, in which the bearing

is very nearly west to east. The prominences on the rock ledge appear to sustain the eastward rather than the westward direction of movement, but they are so slight that some distrust of this interpretation is felt. The harmony with the westward-bearing striæ and lack of harmony with the eastward would be in favor of their classification with the former. It will be noted that two exposures north of Burlington are eccentric in showing bearings S. only 15° and 33° E. All the striæ in the vicinity of Burlington are found at elevations 100 feet or more above the level of the Mississippi, or at about the general level of the higher portions of the rock surface.

The glacial origin of certain striæ at Alton, Illinois, has been called in question by Prof. J. E. Todd.[1] The striæ first seen at that city occur beneath a culvert on Piasa street, in a small valley near the round house of the Chicago and Alton Railway, at a level perhaps 30 feet lower than the higher part of the rock ledges of the immediate vicinity. Todd has expressed the view, in the paper just cited, that these striæ were produced by a horizontal slipping of rock ledges, and that they are now exposed through the removal of ledges which once covered them. Numerous exposures of slickensides and slight faults appear in that vicinity, showing that it is a district where disturbances have occurred. He recognized, as has the writer, that the striæ bear a strong resemblance to glacial striæ, but as glacial striæ and slickensides are both produced by the movement of rock upon rock, he urged that the resemblance to glacial striæ does not forbid their being considered slickensides. Since the appearance of Todd's paper the writer has reexamined this ledge and found satisfactory evidence that the striæ are not slickensides. The striation occurs on three different layers of surface rock. Now, if it was produced by rock ledge slipping upon rock ledge, we should expect the striation to occur between these layers as well as on their exposed surfaces, but an examination showed that the striation is confined to the exposed surfaces, and that the striating agency must have been such as could affect only the exposed surfaces.

Furthermore, following the Chicago and Alton Railway track northward from this exposure, two other striated surfaces were found at levels

[1] Striæ and slickensides at Alton, Illinois, by J. E. Todd: Proc. Am. Assoc. Adv. Sci., Vol. XL, 1891, pp. 254, 255.

about as high as are reached by the limestone in that vicinity. These surfaces had been exposed by the removal of till in the railway cuttings and were overlain by several feet of unmodified till. The glacial origin of these striæ seems supported, therefore, by the character of the striation, the position of the striæ, and the character of the overlying beds.

The striæ observed by Prof. G. F. Wright in Jackson and Williamson counties, Illinois, are the southernmost ones yet found in the drift-covered region of eastern North America. Wright states that the glaciation is as heavy as is often found at points some distance within the glacial boundary. They are scarcely more than 5 miles from the extreme limit of glaciation, and bear directly toward the glacial boundary. Those noted by the writer a few miles northwest from Murphysboro are also very heavy glacial grooves and are situated equally near the glacial boundary.

The striæ in Greene and Owen counties, Indiana, are usually found on a firm sandstone. Those observed by the writer near Worthington are heavy grooves. The character of the glaciation at points reported by other observers appears from descriptions to be as vigorous as at the points just considered. The remarkable variation in bearing in Owen County is worthy of further investigation.

The bearings of the striæ in the vicinity of the Wabash Valley in Clark County, Illinois, and in Vigo and Sullivan counties, Indiana, give rise to some surprise, for the striæ appear to show no disposition to radiate toward the neighboring portion of the glacial boundary on the southeast. Dr. J. T. Scovell, who made all these observations in the vicinity of the Wabash, reports that there is heavy glaciation at each exposure.

In the list of striæ given below four exposures are reported from northern Illinois which are situated within the limits of the Iowan drift. It is not certain whether they were produced at the Iowan invasion or at the Illinoian. They appear to be in harmony with the general movement of the ice sheet at the Illinoian stage as well as at the Iowan. These exposures were in each case first observed and reported by Mr. I. M. Buell, and are said to be very faint compared with the striæ seen by him within the limits of the Wisconsin invasion. The list given below is restricted to the district outside the Wisconsin drift, the striæ within the limits of the latter drift being included in a table presented later (pp. 412–414).

Table of striæ outside the Shelbyville moraine.

Location.	Bearing.	Observer.
Near Winnebago, Ill., at quarry in sec. 6, T. 26, R. 11 E	S. 75° W	Buell.
Bluff of Kents Creek near Rockford, Ill., two exposures, secs. 28 and 29, T. 44, R. 1 E.	S. 75° W	Do.
Cutting on Chicago, Milwaukee and St. Paul Railroad, west of Fielding, Ill.	S. 65° W	Do.
Cutting on Chicago, Milwaukee and St. Paul Railroad, east of Fielding, Ill.	S. 75° W	Do.
East bluff of Mississippi near Gladstone, Ill	S. 79° W	Leverett.
Court and Prospect streets, Burlington, Iowa	S. 72° W	Leverett & Fultz.
North Hill, Burlington, Iowa	S. 65° E	Leverett.
West Burlington, Iowa	W.-E	Do.
Do	S. 75° E	Fultz.
Flint Creek bluff, northwest of Burlington, Iowa	S. 73° E	Do.
One-eighth mile from preceding	S. 33° E	Do.
About 5 miles north of Burlington, Iowa	S. 15° E	C. A. White.
Near Kingston, Des Moines County, Iowa. Main set of striæ. (Scattering striæ S. 30° 15′ E., S. 60° 30′ E., S. 72° 15′ E.)	S. 64° E	Fultz.
One-half mile from preceding	S. 70° E. ±	Do.
Five miles north of Hamilton, Ill., line of secs. 4 and 5, T. 5, R. 8 W.	S. 65° E	Leverett.
West of Havana, Ill., in sec. 6, T. 3 N., R. 3 E	S. 103° W	Do.
Alton, Ill., on Piasa street	S. 40° W	Do.
Cuttings on Chicago and Alton Railroad, north of Alton	S. 30°-40° W.	Do.
Six miles northwest of Murphysboro, sec. 10, T. 8, R. 3 W	S. 30° W	Do.
One and one-half miles southwest of Carbondale, Ill	S. 5° W	G. F. Wright.
Southwest corner of Williamson County, Ill	S. 10°-15° E	Do.
Two miles northeast of Marshall, Ill	S. 20° W	Scovell.
Two miles southeast of Farmersburg, Ind	South	Do.
Southeastern part of Linton township, Vigo County, Ind	South	Do.
Northern part of Linton township (sec. 3)	S. 20° W	Do.
One mile northeast of Worthington, Ind	S. 72° E	Leverett.
Two miles south of Putnamville	N.-S	Collett & Brown.
Sec. 6, T. 7, R. 4 W., Greene County, Ind	S. 80° E	Siebenthal.
Romona, Ind	S. 18° E	Do.
Three miles south-southwest of Vandalia, Ind	W.-E	Wright.
Five miles west from preceding	S. 40°-50° E	Do.
Near Bowling Green, Ind., sec. 19, T. 11, R. 5 W	S. 26° 30′ E S. 30° 35′ E	Collett.
Sec. 35, T. 11, R. 6 W	S. 26° 30′ E S. 29° 30′ E	Collett.
Sec. 6, T. 11, R. 5 W	S. 26° 30′ E	Do.
Sec. 1, T. 11 N., R. 6 W	S. 34° E	Leverett.
Do	S. 36° 56 E	Collett.
Three miles south-southwest of Bowling Green	S. 32° 10′ E	Do.
Near Cloverdale, Ind	S. 0° 35′ W	Jenkins.

EFFECT OF THE ILLINOIAN ICE INVASION ON THE OUTER-BORDER DRAINAGE.

A most important question connected with the Illinoian invasion is its effect upon the drainage lines of the border districts. The slope of the region west of its western border in Iowa is directly toward that border, and the large streams had apparently opened channels to about the present line of the Mississippi prior to the invasion of this ice sheet. The ice nowhere extended more than 20 miles beyond the present valley of the Mississippi, but it covered that valley for a distance of over 100 miles. It apparently furnished an obstruction of such consequence that the question of a more or less complete displacement of the main artery of drainage naturally suggests itself.

On the southwest, below Keokuk, Iowa, the ice sheet failed to cover the Mississippi and the obstruction to the drainage disappears. At the south the terminus was near the crest of the elevated ridge that crosses southern Illinois, and no streams discharged toward the ice margin. On the southeast a part of the border touches an elevated tract, whose natural course of drainage appears to have been toward the ice margin. The amount of drainage obstruction in that region becomes, therefore, an important question.

TEMPORARY DISPLACEMENT OF THE MISSISSIPPI.

That the Illinoian ice invasion did not permanently displace the portion of the Mississippi which it covered is certain, for a considerable section of the present course of the stream crosses the territory covered by the Illinoian drift. Furthermore, this section of the river follows, in the main, the line of a preglacial valley which appears to have been the main artery of drainage for this region down to the time of the Illinoian invasion, except perhaps during the Kansan invasion. The rapids between Montrose and Keokuk, 12 miles in length, and the rapids and narrow portion of the Mississippi Valley between the mouth of the Wapsipinnicon and Muscatine, 40 miles in length, are the only departures made by the river from the line of broad preglacial valleys. The latter displacement is not such as to coincide with the border of the Illinoian drift, and was apparently not determined by this invasion. There remains, then, but the stretch of 12 miles at the lower rapids, in which the present stream has opened a new course, that even approximately coincides with the Illinoian drift border.

But turning from the question of a permanent displacement to that of a temporary one, the influence of the Illinoian invasion becomes more apparent. Several years ago the writer found a large abandoned valley in Lee County, Iowa, shown in fig. 4 (p. 468), which leads southeastward across the county from Big Cedar Creek, a tributary of Skunk River, to the Mississippi River, which it joins about 6 miles below Fort Madison. This large valley is now occupied for a few miles by East Sugar Creek, a small tributary of the Mississippi. This abandoned valley was at first supposed to have been the former course of Big Cedar Creek, which now makes a singular deflection to the north, near its mouth, and this interpretation was published in 1885.[1] A few years later (in 1894) the writer began systematic investigations in southeastern Iowa and found evidence that the valley has a continuation northward from Lee County along the north-flowing portion of Cedar Creek past Skunk River, the present valley of that stream being along it for a few miles above the village of Rome, in Henry County. The study that season did not develop evidence of the further continuation of the valley. But in 1896 the district between the Skunk and Iowa rivers was examined, to determine whether the upper Mississippi with its western tributaries did not utilize this abandoned valley during the Illinoian invasion. This study resulted in the discovery of an abandoned channel which leaves the Iowa River just north of Columbus Junction and passes southward immediately outside the limits of the Illinoian drift to the valley of Crooked Creek near Winfield, and thence westward to Skunk River along a double channel, the northern one being now occupied by Crooked Creek, while the southern is only partially occupied by a stream. It thus appears that the waters of the Iowa, with its main tributary, Cedar River, as well as of Skunk River and Big Cedar Creek, have followed this abandoned channel southward around the western edge of the Illinoian drift. To complete the connection at the north and show that the Mississippi follows this channel it was only necessary to utilize results already obtained by W J McGee and J. A. Udden. Professor Udden three or four years previously conceived the idea that the Mississippi, either in preglacial or in interglacial time, had taken a southwestward course from the Wapsipinnicon to Cedar River, through a broad sag now drained in opposite directions by streams each of which is called

[1] The deflection of Big Cedar Creek, by Frank Leverett: The Aurora, Iowa Agr'l College Monthly, November, 1885.

Mud Creek. The sag leaves the Wapsipinnicon a few miles east of Dixon and comes to the Cedar River at its bend near Moscow, passing just west of Durant and through Wilton. Its course may be seen by reference to the Durant and Wilton Junction sheets of this Survey. The north end of this portion of the valley was occupied by the Iowan ice sheet, which has in a measure concealed its erosion contours, though the valley may still be traced without difficulty. It is now thought to have been utilized by the Mississippi at the Illinoian stage of glaciation.

The point at which the Mississippi was deflected into this old channel was probably at the mouth of the Maquoketa (see glacial map, Pl. VI), from which point it had southward course through the Goose Lake channel, brought to notice by McGee[1], to the Wapsipinnicon, coming to that valley near the mouth of the Wapsipinnicon, as may be seen by reference to the topographic map of that region, Pl. XVIII (in pocket). Perhaps the Mississippi also occupied its present channel from the mouth of the Maquoketa to the mouth of the Wapsipinnicon. The only apparent objection to this view is the possibility that the Illinoian ice sheet obstructed the present course of the river. This being a region in which the Iowan invasion obliterated the marginal features of the Illinoian drift it becomes a difficult matter, as already noted, to determine the precise position of the Illinoian boundary. It probably encroached but a few miles at most on the Iowa side of the river above the mouth of the Wapsipinnicon.

This abandoned course of the Mississippi can be studied to best advantage in the portion south from the Iowa River, as the northern portion has been greatly modified by the Iowan ice invasion. The description, therefore, begins at the point where the old channel departs from the Iowa River. As above noted, the course of the channel is southward from just above Columbus Junction to the vicinity of Winfield, a distance of 12 miles, crossing Long Creek, a small tributary of the Iowa, about 6 miles south of Columbus Junction. The bed of the old channel is about 120 feet above the level of the Iowa River bottom at Columbus Junction, or very nearly 710 feet above tide. It is cut to a depth of 25 to 35 feet below the bordering plain, and has a width of $1\frac{1}{4}$ to $1\frac{1}{2}$ miles. Its depth and breadth are not much greater than that of the present Mississippi within its

[1] The drainage systems and loess of eastern Iowa, by W J McGee, private publication, 1884. Also the Pleistocene history of northeastern Iowa, by W J McGee, Eleventh Ann. Rept., U. S. Geol. Survey, 1891, pp. 227, 228.

banks, and it has the appearance of being a stream channel or bed rather than a valley proper, the only flood plain being the bordering uplands. A fine view of the valley may be obtained just west of Columbus. Before reaching Winfield a channel branches off to the west from the main channel and joins it again just south of Wyman. This channel has a breadth of but one-eighth mile or less. It is more direct than the main channel, and has about the same depth.

A short distance east of Winfield the main channel is entered from the east by the East Fork of Crooked Creek, and this stream meanders through the broad bottom of the main channel westward to its junction with the West Fork, and thence continues west and south to Skunk River Valley at Coppock. Another channel leads directly west from Winfield past Wayne to Coppock, a distance of 15 miles. The combined width of the two channels is but little greater than that of the portion of the channel north from Winfield, the channel along Crooked Creek being about three-fourths to 1 mile in width and the channel leading past Wayne one-fourth mile. The lower portion of Crooked Creek nearly occupies the full width of the north channel, but throughout the greater part of the course it is bordered by a broad terrace-like plain, several times the breadth of the valley which it has excavated. The depth of about 25 to 35 feet continues, as in the portion north from Winfield.

The portion along Skunk River from Coppock to Rome, a distance of 10 miles, is so completely occupied by the valley of that river that only occasional narrow remnants of the abandoned channel appear as terraces on its borders, the average breadth of that part of Skunk River Valley being fully 1 mile. The most extensive remnant of the abandoned channel is found in the double oxbow made by the river north and west from the village of Rome, which stands, where not broken down by subsequent erosion, about 670 to 675 feet above tide.

From Rome the abandoned valley continues southward along the valley of Big Cedar Creek (reversed) and is preserved in terracelike remnants on each border of the valley which stand 30 feet or more below the level of the upland plain. The average breadth of the valley being not less than one-half mile the terrace remnants are narrow. From the bend of the Big Cedar, 8 miles south of Rome, the old valley, as noted above, leads southeastward across Lee County to the Mississippi Valley at Viele, 6 miles below Fort Madison, gradually deepening from 30 feet at the north to 50

or 60 feet at the south. It is occupied for about 4 miles by Little Cedar Creek just south of the bend of Big Cedar. The remainder of its course is drained by Sugar Creek. The excavation along the channel from Columbus Junction to Viele is estimated to be one-half a cubic mile.

The precise elevation of the bottom of this old channel has been determined at only a few points in the portion south from Columbus Junction. The elevation at the border of the Iowa River 12 miles north of Winfield is apparently not more than 710 feet. At Winfield its elevation is about 10 feet below the railway station or 703 feet above tide. The altitude appears to fall but little in the 15 miles between Winfield and Skunk River. The aneroid determinations made at Coppock give the old channel an altitude of about 700 feet above tide. In the oxbow near Rome the altitude is about 675 feet. At the point where the Keokuk and Northern Railroad crosses the channel, near the line of Henry and Lee counties, the elevation is 657 feet. At St. Paul station on the Fort Madison and Des Moines Railroad 5 miles southeast, the elevation is 645 feet, and at the point where the channel joins the Mississippi, 14 miles farther southeast, about 620 feet. The distance from the point where this channel leaves the Iowa River to its junction with the Mississippi is about 75 miles. The fall of 90 feet which it makes in this distance would therefore give an average of slightly more than 1 foot a mile. The fact if it be proved that the channel has no fall in the portion leading west from Winfield may bring support to the hypothesis suggested by studies farther north that the surface has been subjected to a westward differential uplift in the later part of the Pleistocene.[1] The measurements of altitude, however, are not sufficiently exact to justify the presentation of these data in support of the hypothesis.

The writer has been unable to discover any notable amount of sand or gravel in the bed of this channel. It generally appears to be swept clean of such deposits. The valley is coated with a sheet of loess similar to that which occurs on the bordering uplands, but this deposit is apparently as late in deposition as the Iowan stage of glaciation, in which case it can not be considered as a deposit of the stream which formed this channel. In northwestern Lee County sand to a depth of 10 to 20 feet is found along the channel. Chamberlin has suggested that the ground in which this channel was excavated may have been frozen at the time of the Illinoian glaciation, its situation being on the immediate border of the ice sheet, and

[1] See Chamberlin: Third Ann. Rept. U. S. Geol. Survey, p. 391.

the frozen condition of the ground may have prevented the stream from eroding more material than it could readily transport. In that case the material should be accumulated in portions of the Mississippi Valley to the south, where the gradient became too low to admit of its being swept along. In apparent support of this view there is found, immediately below the Des Moines or lower rapids of the Mississippi, a marked filling of the valley with deposits of sand and fine gravel. This filling may be seen to good advantage at and below the village of Warsaw, which stands on a terrace of aggradation antedating the loess in its formation and apparently separated from the Kansan glacial stage by an erosion interval of considerable length.

The Warsaw exposures were examined by the writer in 1894 and reexamined by Professor Chamberlin, Dr. H. F. Bain, and the writer in the summer of 1896, when the relationships given above were worked out. The Kansan till has suffered erosion to a level but little above the present stream and a bowlder bed marks the junction of this till with the overlying sand and gravel. This bowlder bed is continued on the north side of the river in Keokuk, as pointed out by Prof. C. H. Gordon.[1] The sand and gravel deposits are typical fluvial material and are built up to a height of about 80 feet above the river. At their top is an ashy silt resembling a soil but perhaps redeposited as flood-plain material, and above this a deposit of sand grading upward into loess, the sand and loess together being 20 to 25 feet in thickness. Opposite Warsaw near the mouth of the Des Moines River there is a somewhat different exposure of fluvial filling known as the "Yellow banks." This has been examined, both by the writer and by Professor Gordon, and the following section was published in the Geology of Iowa in 1895:[2]

"*Yellow-banks" section, near Keokuk, Iowa.*

	Ft.	in.
Clay, yellow, pebbleless	5	
Silt, drab, pebbleless	1	3
Earth, black, with a few small pebbles; apparently an old flood-plain deposit	12	
Clay, yellowish (local)		6
Sand, with a few small pebbles; layers of bowlders 1 foot thick at base	20–25	
Earth, black, with yellow streaks; apparently an old flood-plain deposit	3–	6
Gravel, with some sand beds; pebbles 2 inches or less in diameter	20	
Blue clay, till, exposed	15	
Total	85	

[1] Iowa Geol. Survey, Vol. III, 1895, pp. 252–254.

[2] Op. cit., p. 243.

BOWLDER BED AT KEOKUK, IOWA.

deposits of sand and silt that seem referable to the valley filling at the Illinoian stage of glaciation and which antedate the loess by a long period, as shown by weathering. The surface of the sand presents a deep red stain to a depth of 3 or 4 feet below the base of the loess, and contrasts strongly in color and weathering with the sand at greater depth as well as with the overlying loess. The weathered zone here is apparently the correlative of the black earth found below the loess at the "Yellow banks." Excellent exposures of this weathered zone may be seen at the corner of Second and Timea streets in Keokuk.

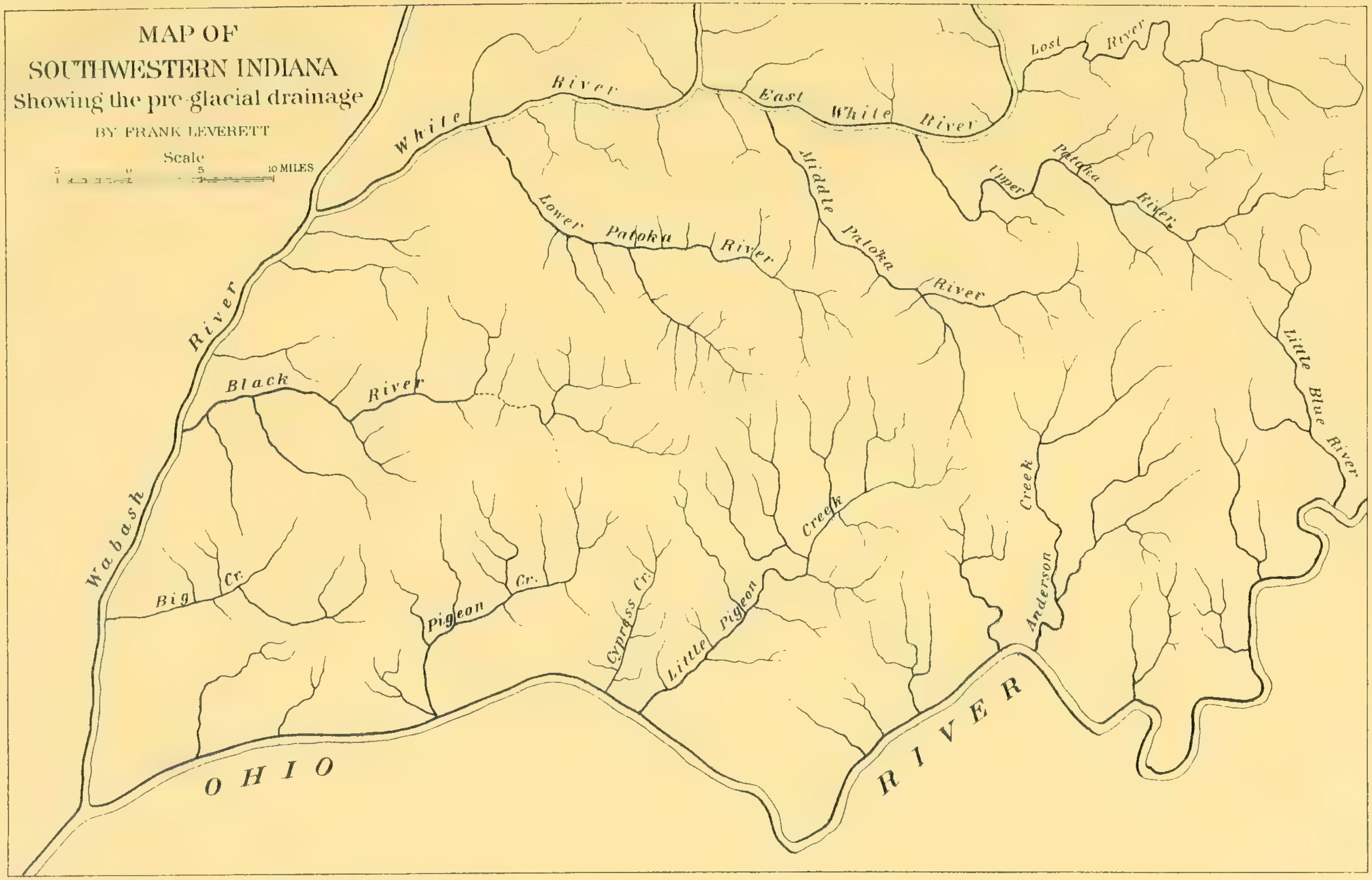
Examinations have been extended down the Mississippi on the Illinois side, and it is found that the altitude of the valley filling decreases more rapidly than the fall of the present stream. At a point opposite Hannibal, Missouri, where Hadley Creek enters the valley from the east, the filling reaches a level only 15 or 20 feet above the broad bottom of the Mississippi or scarcely 35 feet above the stream, and about 90 feet below its altitude at Warsaw, 45 miles up the valley. This rapid increase in the amount of filling apparently supports the view that material was swept into the valley and there deposited in delta-like fashion.

Returning to the discussion of the abandoned channel, and taking up the portion northeastward from the Iowa River, it is found that it has slightly lower altitude than the portion in the district south from the Iowa River, much of it being below 700 feet above tide. In explanation of this lower altitude it is suggested that the section to the north of the Wapsipinicon River and possibly the portion between the Wapsipinicon and Iowa rivers may have been occupied by the Mississippi for a considerable period after the southern portion had been abandoned. Possibly it persisted in the occupancy of its channel until the Iowan ice invasion forced it out.

The broad valley of the southwestward flowing portion of the Cedar appears to have held a lake at the Illinoian stage of glaciation for which Udden has recently suggested the name "Lake Calvin." The features of this old lake bed are discussed by Udden in a report on the geology of Muscatine County, Iowa.[1]

The abandonment of the lower end of the channel from Columbus Junction southward probably occurred as soon as the ice sheet had withdrawn sufficiently to uncover the present line of the stream, for the altitude

[1] Iowa Geol. Survey, Vol. IX, 1899, pp. 350-357.


MAP OF
SOUTHWESTERN INDIANA
Showing the pre-glacial drainage
BY FRANK LEVERETT
Scale
5 0 5 10 MILES
White River
East White River
Lost River
Upper Patoka River
Middle Patoka River
Lower Patoka River
Little Blue River
Wabash River
Black River
Big Cr.
Pigeon Cr.
Cypress Cr.
Little Pigeon Creek
Anderson Creek
OHIO RIVER

MAP OF SOUTHWESTERN INDIANA SHOWING THE GLACIAL BOUNDARY AND PRESENT DRAINAGE

BY FRANK LEVERETT.

Scale

5 0 5 10 15 MILES

1898

along the present Mississippi bluffs is a few feet lower than the bed of the abandoned channel. This lower altitude along the Mississippi is due to the incomplete filling of the preglacial channel by drift.

CHANGES OF DRAINAGE IN SOUTHWESTERN INDIANA.

The Illinoian invasion produced important drainage modifications in southwestern Indiana, only a part of which have as yet been fully worked out. The present discussion aims to deal chiefly with the changes which have received the most careful attention. The discussion begins with streams in the southwest corner of Indiana.

By reference to the map, Pl. VIII, it will be seen that the greater part of Posey County and adjacent portions of Vanderburg and Gibson counties are now drained westward into the Wabash through Big Creek. The South Fork leads almost directly west from near Evansville in Vanderburg County to its junction with the North Fork in central Posey County. The North Fork leads northwest from northern Vanderburg across southwestern Gibson into Posey County, and there near the village of Cynthiana turns southwestward and maintains this course to the Wabash. It receives a tributary from the southeast near the crossing of the Peoria, Decatur and Evansville Railway, but no other tributary of importance enters above its junction with the East Fork. An examination of the head-water portion of the North Fork has brought to light decisive evidence that its preglacial line of discharge was westward into Black River and thence to the Wabash at a point 20 miles or more above the present mouth of the creek. A broad valley deeply filled with drift leads from Big Creek westward to Black River, passing just north of the village of Cynthiana. The abandoned valley is nearly a mile in width, while the new passage is scarcely one-tenth of a mile in width. The creek soon enters another old valley whose head water portion is occupied by the southeastern tributary referred to above, but whose lower course is abandoned. The Peoria, Decatur and Evansville Railway utilizes the abandoned valley between Big Creek and Poseyville. From Poseyville the valley passes northwest to Black River. In the narrow valley near Cynthiana the present stream thus cuts across a low ridge separating two streams, which formerly drained northwestward into Black River. Below the railway crossing Big Creek soon enters a

narrow valley and crosses the preglacial divide between Black River and the South Fork of Big Creek. Thus the latter drainage basin has been greatly enlarged at the expense of the former. The glacial boundary follows nearly the present course of the North Fork of Big Creek below Cynthiana, and the location of the new stream across the rock point near that village is evidently due to the presence of the ice sheet in the lowlands to the west, and the diversion across the divide between the preglacial drainage basins of Black River and Big Creek is due to occupancy of the former by the ice sheet.

The Pigeon Creek drainage basin has also been enlarged at the expense of Black River. Muddy Fork of Pigeon Creek lies in a lowland which connects on the southwest with Black River, and this lowland apparently received the portion of the Pigeon Creek drainage in Gibson and northern Warrick counties. The location of the col was not definitely worked out, though it is in all probability east of Elberfeld, in T. 4 S., R. 9 W. Upon referring the question of changes of drainage in the Pigeon Creek basin to Dr. George H. Ashley, of the Indiana survey, who has made an examination of the portion in Warrick County outside the limits of the writer's own examinations, the following reply was received:[1]

> I think you are right in believing that the head waters of Pigeon Creek drained to the west in preglacial times, the divide running nearly east and west across the center of T. 4 S. through Rs. 8, 9, and 10 W. The present course of Pigeon Creek through Ts. 4 and 5 S., R. 9 W., while not so markedly a postglacial channel as many to be found, has nevertheless several of the characters of such a channel. In the first place the bottoms are narrow, averaging probably less than one-half mile in width from above Elberfeld to below Millersburg, or scarcely half the usual width of the west-flowing head-water portion. Secondly, the bluffs are more abrupt than is usual for streams of this size in that region. This is especially true north of east from Elberfeld, where the stream appears to have crossed an old divide. Thirdly, the short tributaries on each side of the streams in the vicinity of the supposed divide also sustain this view. Fourthly, reports suggest that rock is to be found within a dozen feet below the stream bed in this narrow portion, but this has not as yet been verified.

The changes of drainage become still more important in passing northeastward into Pike and Dubois counties. The streams which formerly had a northwestward discharge into the White River drainage have been turned westward just outside the glacial boundary to form the Patoka River, as

[1] Letter written June 8, 1898.

may be seen by reference to the map, Pl. VIII. These perhaps may be discussed to best advantage by beginning at the east with the head waters of the Patoka.

The portion of the Patoka above Jasper seems to be following a preglacial line, but at that town a deflection of the stream into another drainage basin has been effected. The preglacial valley is easily traced from the Patoka, in sec. 24, T. 1 S., R. 5 W., northwestward to Mill Creek Valley and thence into East White River. Its breadth is about 1½ miles, and it has been filled with sand and loess-like silt to a height of 30 to 35 feet above the present level of Patoka River, in sec. 24, or to about 490 feet above tide. This filling was sufficient to turn the stream across a low divide in the east part of Jasper. In opening a passage across this divide the stream has accomplished a remarkably small amount of work. The narrow part of the valley which marks the position of the old divide is only about one-half mile in length, 600 to 800 feet in width, and 20 to 35 feet in depth. The stream is reported to be several feet in depth through this narrow portion, thus increasing the depth of erosion perhaps 10 feet. There is in part of the gorge a thick-bedded sandstone which has probably greatly resisted lateral erosion.

Immediately south of Jasper the present Patoka River enters a valley fully 1 mile in width which constitutes the preglacial line of discharge for several southern tributaries entering in Dubois County. The valley is not occupied far by the present stream, but leads from Jasper in a course north of west into Pike County, passing south of Ireland and directly under the village of Otwell, its course for several miles being nearly coincident with Flat Creek, though in the reverse direction. Whether it joined the East White Valley near Highbanks or entered a few miles below, at the mouth of Mud Creek, is undetermined. There are shallow valley-like depressions connecting the abandoned valley with East White River along each course which are underlain by heavy deposits of drift, each of which apparently has a width sufficient to have accommodated the old stream. Probably, however, one of these lines will be found to be separated from the old valley by a concealed rock barrier. This old valley, as above noted, has a rock floor considerably below the present bed of the neighboring portion of East White River, a boring at Otwell having failed to reach rock at a level about 35 feet below the river.

The present Patoka River leads southward from Jasper for several miles, occupying the northern end of the broad valley of Hunleys Creek, a southern tributary of the abandoned valley just discussed. The river then takes a northwestward course, cutting across a narrow neck of upland and touching the border of the abandoned valley about 2 miles south of Ireland. In this passage across the neck of upland the width of the flood plain is nowhere less than one-fourth of a mile, or about double the width of the valley bottom in the gorge at Jasper. Whether this difference in size is referable to variations in the texture of the rock or is due to difference in date of deflection has not been determined. It seems, however, not improbable that this narrow neck had been encroached upon by valleys on each side and severed from the main upland prior to the glacial invasion.

After touching the old valley near Ireland, the Patoka turns to the southwest and near the line of Dubois and Pike counties enters a narrow valley 800 to 1,000 feet in width. The narrow portion extends from the county line southwest about 2 miles to the mouth of Rocky Creek, a southern tributary. It there expands to twice or three times the width of the narrow portion and from that point gradually increases in width down the stream, reaching nearly 2 miles in western Pike County. The narrow portion evidently marks the position of a preglacial divide. That this divide had been reduced to a low elevation is shown by neighboring cols, which, though low, were not utilized by this stream in selecting a new course. One of these cols at the village of Velpen stands only 510 feet above tide. It is probable that the blockaded stream had to rise no higher than 500 feet to cross the divide, or to a height of less than 75 feet above its present level; possibly the divide was not more than 475 feet at the col. The latter altitude is slightly lower than the sand and silt filling made by Lake Patoka which, as above noted, is found in the abandoned valleys to the north and east of this divide. This filling is conspicuous in the vicinity of the divide as well as above, and seems to pass down the present stream beyond the divide without appreciable decrease in altitude. The col was nearly if not quite covered by silt before the present channel was opened across it.

The Patoka River apparently follows the line of a preglacial stream from the mouth of Rocky Creek, in eastern Pike County, westward into Gibson County to the bend about 6 miles above Patoka. It there is in a low tract which extends northward to White River. But instead of follow-

ing this lowland it continues westward and passes through a range of hills which leads northward from Princeton past Patoka to White River at Hazelton. This deflection lies within the glaciated region and calls for a somewhat different explanation from those just considered. It is probable that a lower passage was afforded across a col near Patoka than the lowland to the north else the stream would not have suffered this deflection. In the passage through this range of hills at Patoka the valley is reduced to a width of scarcely one-half mile or to about one-fourth the width of the preglacial valley which it occupies a few miles to the east. Upon passing this range the stream soon enters the broad valley of the Wabash and takes a somewhat direct course into that river.

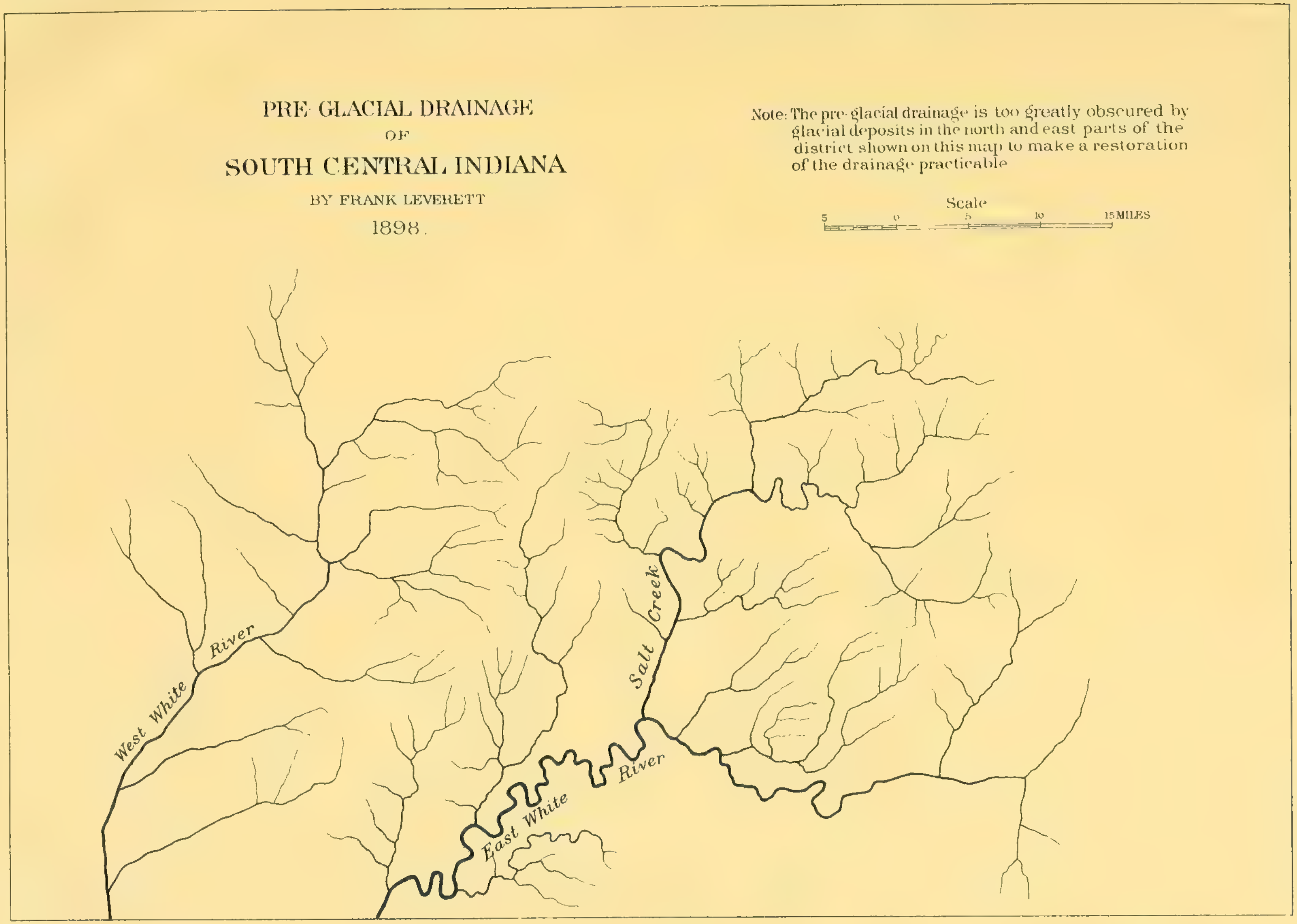
Since Patoka River enters the glaciated region in its lower course the question arises whether it found discharge beneath the ice margin during the time when its lower course was covered by the ice sheet or found a line or lines of discharge southward through the unglaciated region into the Ohio. There is a col on the divide between Patoka and Ohio rivers crossed by the abandoned Wabash and Ohio Canal about 1 mile southwest of Francisco, which stands only 480 feet above tide, or about the altitude of the silt deposits along the Patoka in western Dubois and Pike counties. From this col there is an open line into the head waters of Pigeon Creek. But as noted above there may have been another col in northern Warrick County on the present line of Pigeon Creek to offer resistance to the discharge of water to the Ohio. It is doubtful, however, if that col stood any higher than the one near Francisco, and it may have been so low as to afford an easy passage for the stream. An examination of the col near Francisco failed to bring to light decisive evidence that a stream had crossed it. The sag crossing the divide is scarcely 100 rods in width and is not bordered by banks or well-defined erosion contours. The features seem to be no different from those of other sags at higher altitudes on the divide. The canal cuts through about 12 feet of loesslike yellowish-brown earth before striking the rock surface, which is similar to the material found on border districts at all altitudes. It seems less probable that cols on the Patoka-Ohio divide farther east were utilized, for they stand considerably higher than the col under consideration; the lowest stand probably about 525 to 550 feet above tide. The col crossed by the railway near Ferdinand station, 7 miles south of Huntingburg, is probably as low as any, standing 530 feet

above tide. The sag leading across this divide, like that near Francisco, is too narrow to have suffered much erosion by a stream discharging across it. On the whole the evidence of southward discharge into the Ohio seems very weak, and the view that the water which accumulated along the ice margin in Dubois and Pike counties found its main discharge to the Wabash under the ice margin, appears more probable. At most the col near Francisco appears to have served only temporarily as a waste weir for the accumulated waters.

Several interesting deflections of small streams have been noted in the vicinity of the glacial boundary in the district lying between East White and the main White River. These have been brought to light by the studies of Mr. C. E. Siebenthal, of the Indiana geological survey, with perhaps one exception, that of Furse Creek in northwestern Martin County. Siebenthal has kindly furnished notes on these changes of drainage in advance of the publication of his report. Since receiving his notes the writer has had opportunity to examine some of the deflections brought to light by Siebenthal, but for the detailed examination, as well as the discovery of these deflections, Siebenthal should receive credit. It is scarcely probable that all the deflections have been brought to light, for the valleys of some streams in Daviess County have not been given sufficient attention to warrant their discussion. The first deflection discussed is that of Furse Creek, after which the streams examined by Siebenthal are taken up in order from south to north.

Furse Creek as shown in Pl. IX, strikes the glacial boundary about 2 miles east from the west line of Martin County. It there turns abruptly southward and enters a gorge in the southeast part of sec. 8, T. 5 N., R. 4 W., in which the creek bluffs border the stream closely on each side for a mile or more. The stream then enters an open valley formed by the small southern tributary which joins it in sec. 18. Whether it has suffered other deflections below this point has not been determined. From the point of deflection in sec. 8 a lowland tract heavily coated with drift leads northwestward to the valley of Doans Creek, near Scotland. This probably was the preglacial line of discharge for Furse Creek.

Siebenthal has found that Richland Creek was deflected southward near the point where it strikes the glacial boundary 1½ miles east of the village of Newark, its old course having been northwestward from that point. The position of the col on the old divide below the point of deflection of the creek is clearly shown in a view from a hill southeast of Newark.


PRE-GLACIAL DRAINAGE
OF
SOUTH CENTRAL INDIANA
BY FRANK LEVERETT
1898.
Note: The pre-glacial drainage is too greatly obscured by glacial deposits in the north and east parts of the district shown on this map to make a restoration of the drainage practicable
Scale
5
0
5
10
15 MILES
West White River
Salt Creek
East White River

GLACIAL MAP OF SOUTH CENTRAL INDIANA

BY FRANK LEVERETT.

Scale

5 0 5 10 15 MILES

1898

The bluffs close in on either side of the creek near the center of sec. 19, sloping gradually to the border of the stream. The stream has cut a notch nearly 100 feet in depth across the col. It soon enters a small preglacial valley, but appears to follow the course of that valley for only a short distance. Its course for about 8 miles is mainly across rock points and low divides and lies just outside the glacial boundary. At its junction with Beech Creek a preglacial valley is found, but the stream turns out of this valley in sec. 9, T. 7, R. 4 W., and takes a direct course westward through a gorge, thus cutting off a rock point on the south side of the preglacial Beech Creek Valley. It reenters the old valley near the corners of secs. 7, 8, 17, and 18, after traversing a gorge for about 1½ miles, and is reported by Siebenthal to continue in a preglacial valley to its mouth. The stream lies within the glaciated region throughout the portion below the mouth of Beech Creek, but is only about 5 miles by direct line inside the glacial boundary at its entrance into White River. It seems probable that the stream discharged through the low glaciated districts bordering White River, even at the maximum extension of the ice, for no line of discharge is found across the elevated districts outside the glacial boundary.

In the head-water portion of Richland Creek, above the point of deflection from its preglacial valley, there appears to have been a glacial lake for which Siebenthal has proposed the name Lake Richland. The presence of the lake is shown by terraces and deposits of silt and sand which filled the valley up to a definite level. They stand nearly 100 feet above the creek at the point of deflection, but in passing up the valley they gradually approach the creek level, being but 30 or 40 feet above the stream in the vicinity of Whitehall. Whether they are perfectly horizontal has not been determined. The lake apparently extended up the creek a short distance into Monroe County.

About 4 miles south from the point where Richland Creek turns westward into the glaciated district the glacial boundary comes to the west end of another glacial lake whose site is now known as the "American bottom." It extends eastward about 5 miles from the glacial boundary and has an average width of nearly 1 mile. This old lake bottom now has subterranean drainage southwestward through sand deposits to a tributary of Clifty Creek, where it appears in the form of springs. Because of the subterranean drainage the plain is preserved in nearly the condition left by the lake.

Passing northward into Owen County there is found a slight deflection in Raccoon Creek, just inside the glacial boundary. Instead of following its old course the creek passes across a rock point on the south, occupying a gorge for about a mile. The head-water tributaries of Raccoon Creek outside the glacial boundary carry terraces of silt and sand which are interpreted by Siebenthal to be the accumulations made in small glacial lakes held in front of the ice sheet.

The "Flat Woods" of eastern Owen and western Monroe counties cover an area of several square miles of elevated land, immediately inside the glacial boundary. The flats in this area are interrupted by hilly tracts, and the entire area is above the general level of border tracts. These features are thought to indicate that no large stream occupied the "Flat Woods" in preglacial times. It is suggested by Siebenthal that the region had a system of subterranean drainage prior to the glacial invasion, but that glacial accumulations have caused a change to surface drainage.[1] The flats are now drained chiefly to the north through McCormack's Creek. The western portion drains westward through Ellison's Branch into White River. On McCormack's Creek there is a fall about a mile from its mouth, above which there is only a shallow, poorly drained valley. The main work of the stream since the Glacial period has been given to the excavation of the gorge below the fall, but no accurate estimate was made of the work accomplished in cutting back to the fall.

The effect of the ice invasion upon the course of White River has been even greater than on the small eastern tributaries which enter it from the unglaciated region. The preglacial drainage is so greatly concealed above the north line of Greene County that it seems impracticable to determine even the course of the main drainage line. The stream is now occupying a preglacial valley for a few miles in southwestern Morgan County, and is also in a preglacial valley throughout much of its course below Owen County. But in its passage across Owen County it is opening a new valley. It has been suggested that this stream had a subterranean passage across the sink-hole region of Owen County, in which case no well-defined surface channel may have been opened prior to the glacial invasion. The available data seem insufficient to test the applicability of this interpretation.

[1] Twenty-first Ann. Rept. Indiana Geol. Survey, 1896, pp. 301, 302.

PLEISTOCENE DEPOSITS BENEATH THE ILLINOIAN TILL SHEET.

Although the Illinoian till sheet throughout much of the region under discussion may rest immediately on the rock, there are, in places, deposits separating it from the rock formations. The deposits are principally of two classes—namely, the Kansan till, with perhaps a somewhat distinct pre-Illinoian till, and valley silts or sands.

KANSAN TILL.

Attention has been called to the till of southeastern Iowa and western Illinois, which underlies the Illinoian drift and which is referred to the Kansan. The full extent of this sheet of till in western Illinois is not determined. Its eastern border comes to the Mississippi Valley from the south near Hannibal, Missouri, and it probably continues northward into Illinois across Adams and Hancock counties. It probably also extends into counties east of the Mississippi farther north, although this has not been so clearly determined. That it extended into western Adams and Hancock counties is shown by at least two lines of evidence. The first line of evidence is that furnished by striation. An exposure of a striated ledge with a bearing S. 65° E. appears on the south side of Wagner's Creek, about 4 miles above Hamilton, Illinois, and 2 miles east of the Mississippi. This, so far as known, is the only instance yet discovered of striation produced by the Keewatin ice field east of the Mississippi and south of the Wisconsin Driftless Area. The striæ reported above in the vicinity of Burlington, Iowa, are in some cases situated on the brow of the west bluff of the Mississippi, showing that the eastward movement extended at least to the Mississippi Valley.

The second line of evidence of the extension of the Keewatin ice sheet into western Illinois is furnished by till deposits separated from the overlying Illinoian by a soil and carrying other evidences of greater age than the Illinoian. In the discussion of the border of the Illinoian drift in Hancock and Adams counties, Illinois, attention was called to the occurrence of a heavy sheet of blue till similar in structure to that found beneath the Illinoian west of the Mississippi, and to a few exposures near the line of Hancock and Adams counties of a black soil separating the till from the overlying Illinoian. In these exposures it was found that the till under the

soil had been leached to a depth of several feet, a feature which testifies to the lapse of a considerable period between the deposition of the two till sheets. This black soil between the tills is also penetrated in wells in western Hancock County.

A possible third line of evidence of the extension of the Keewatin ice sheet into western Illinois is found in the presence of laminated clays in a buried preglacial valley in central Adams County. These clays are conjectured to be due to an obstruction of the lower course of the valley in western Adams County by the Keewatin ice sheet. The obstruction might have formed a lake in which these deposits were laid down contemporaneously with Kansan till.

The lapse of a long interval between the deposition of the Kansan till and the Illinoian is clearly shown in southeastern Iowa, not only by the presence of a soil and leached subsoil between two sheets, but by the markedly greater erosion of the Kansan than of the Illinoian sheet. This erosion is manifest to the trained observer on passing from one sheet to the other. In the district occupied by the Kansan the erosion is so great that only narrow remnants of the original drift plain are preserved along the water partings. But in the district occupied by the Illinoian more than half the original drift plain is preserved, and that, too, on the immediate borders of the Mississippi, where conditions for erosion are more favorable than in the area to the west which is occupied by the eroded Kansan sheet. The great contrast in amount of erosion supports strongly the view that a longer interval elapsed between the Kansan and Illinoian glaciations than between the Illinoian and the present time.

Attention is called, in the discussion of the Illinoian drift border, to an instance of its filling a valley in Des Moines County, Iowa, that had been cut in the Kansan drift. This valley apparently had a depth of 50 feet below the bordering plains, but no data are available concerning its width. It appears from a study of the terraces on valleys cut in the Kansan drift of southeastern Iowa, that the erosion in the interval between the Kansan and Illinoian stages of glaciation was such as to form broad shallow valleys rather than narrow deep ones. The large valleys appear to have been cut to a depth of but 50 or 60 feet, though they had a width of one or two miles.

PRE-ILLINOIAN (?) TILL AND ASSOCIATED DEPOSITS.

As yet the evidence pointing toward the occurrence of drift of greater age than the Illinoian in the districts to the east, which lie beyond the limits of the Keewatin ice sheet, has not sufficient strength to make it seem advisable to advocate a pre-Illinoian till. There are occasional well sections reported to have passed through a bed of wood or of soil in the midst of the till in central Illinois. Thus at Pana a section reported by Worthen is as follows:[1]

Section of well at Pana, Illinois.

	Feet.
Soil and clay	11
Blue clay	4
Sand and gravel	12
Hard red clay	18
Forest bed	3½
Blue clay	57
Black soil or forest bed	2½
Blue clay	19
Total	127

This section is based upon specimens preserved from a test boring with diamond drill. The specimens were recently examined by the writer and some light obtained concerning the interpretation to be put upon this section. The upper 15 feet consists of a pebbleless material to be classified with the loess. The upper forest bed proves to be simply fragments of wood embedded in ordinary till. The till was found to be very calcareous at the horizon of this wood and to show no evidence of atmospheric exposure subsequent to its deposition. The wood appears, therefore, to be simply material deposited in the till by the ice sheet and has no more significance in determining a time interval than the presence of a Paleozoic fossil embedded in the drift. The lower forest bed consists of a humus-stained clay in which fragments of wood occur; it is apparently a soil. Under it is a greenish clay subsoil, such as occurs beneath swamps. This, as well as the soil, is pebbleless. At the bottom of the clay, resting on the limestone rock, there is a thin bed of ferruginous conglomerate, in which angular chert is mingled with waterworn pebbles. No Canadian rocks or specimens which can be referred to glacial action were found. This raises the question whether the conglomerate is not of preglacial age. The soil

[1] Geol. Illinois, Vol. VII, pp. 22–23; also Vol. VIII, p. 15.

at the base of the drift, together with the underlying subsoil, appears to be connected but remotely at least with glacial agencies. The deposit apparently antedated the deposition of the overlying till by a considerable interval. The writer is inclined to refer to the Illinoian invasion the series of clays setting in at 27 feet and extending to 106 feet.

Worthen reports a section at Virginia, Illinois, in which a black soil appears between tills at a depth of 67 to 70 feet.[1] On making inquiry of Dr. J. F. Snyder, of Virginia, concerning this section, it is found that the record of the coal shaft on which Worthen based his section of the drift was not kept with a sufficient degree of accuracy to insure its correctness. Dr. Snyder is of opinion that the distance to rock is about 70 feet greater than shown by this record. It would certainly be hazardous to base an important time interval on the reported occurrence of soil in the shaft at Virginia.

The section of a coal shaft at Bloomington reported by Dr. H. M. Banister[2] represents the occurrence of two buried soils. The section as reported by Dr. Banister is as follows:

Section of coal shaft at Bloomington, Illinois.

	Feet.
Surface soil and brown clay	10
Blue clay	40
Gravelly hard pan	60
Black mold with pieces of wood	13
Hardpan and clay	89
Black mold, etc	6
Blue clay	34
Quicksand, buff and drab in color, and containing fossil shells	2
Total drift	254

In this section the upper 110 feet may be referred with considerable confidence to the Wisconsin drift. The upper "black mold" at 110 to 123 feet was apparently post-Illinoian. It is probable that the Illinoian sheet is represented in the "hardpan and clay" at 123 to 212 feet. The remainder of the section would be therefore pre-Illinoian. Whether the blue clay below the lower "black mold" is a glacial deposit is not clearly shown. It may prove to be a water deposit. In view of this uncertainty it seems unsafe to use this section as evidence for the occurrence of a pre-Illinoian drift sheet in central Illinois.

[1] Op. cit., Vol. VIII, p. 16.

[2] Op. cit., Vol. IV, 1870, p. 178. Also Vol. VIII, p. 14.

In this connection attention is called again to the section of a shaft at Coatsburg, in Adams County, in which a laminated clay of considerable depth underlies the till, but which is not a strictly glacial deposit. The Bloomington section may be of similar character in its lower portion. The sections above discussed comprise the most puzzling ones reported in the geology of Illinois. The buried soils there reported are usually found, when in the district outside the Wisconsin drift, either at the base of the loess, which is a post-Illinoian interval (Sangamon), or at the bottom of the glacial deposits, where only silt or sand occurs between the soil and the underlying rock.

Prof. R. D. Salisbury has reported the occurrence of two sheets of drift in southeastern Illinois and southwestern Indiana. He considers them representatives of two episodes of a single glacial epoch. The upper sheet is thought to extend fully as far as the lower, if not beyond it.[1] As the features referred to by Salisbury have never been investigated by the writer, some hesitancy is felt in offering an interpretation. It is, however, suggested that the invasion limited on the southwest by the ridged drift of the Kaskaskia Basin may have formed the upper sheet, while the invasion, which in southwestern Illinois was the more extensive one, may have formed the lower sheet. Possibly the interval will prove to be too long to support this interpretation. In that case the lower sheet would be referable to a pre-Illinoian invasion.

In northern Illinois there are certain deposits which need consideration in this connection. The studies of Mr. Ira M. Buell in eastern Winnebago County led to the discovery of several exposures of glacial conglomerate which appear along the east bluff of Rock River. Bowlder-like masses of this conglomerate have been incorporated in the till of that region, a good illustration being found in the cuttings of the Illinois Central Railroad, immediately southeast of Rockford. The firm cementation, and also a deep orange-colored stain presented by the conglomerate from which these bowlders are derived, seems to have been produced prior to the deposition of the sheet of till in which they are embedded. This till is probably of Iowan age. It therefore remains to be determined whether the conglomerate is of Illinoian age or of still earlier date. There are other deposits in this region, noted by Buell, which favor the view that there were not

[1] See Arkansas Geol. Survey, Crowleys Ridge, Report for 1889, Vol. II, p. 229.

less than two ice invasions prior to the Iowan. Reference is made to the evidence found in the occurrence or distribution of bowlders of Waterloo quartzite, a subject which has been investigated in considerable detail by Buell and discussed in a recent paper published in the Transactions of the Wisconsin Academy of Sciences.[1]

The earliest movement affecting the ledges of Waterloo quartzite, which has been recognized by Buell, is interpreted by him to have been westward. This movement is indicated by the westward transportation of bowlders from the quartzite ledges, and farther south by the occurrence in the marginal portion of the drift of Devonian and Upper Silurian rocks, which could only have been derived from the east. Following the westward movement, he thinks there is evidence of a southward movement, through which quartzite bowlders were carried into northern Illinois. He considers the western margin of the ice lobe which transported this material to be indicated by a "belt of thickened stony till and kame-like gravel deposits, the former appearing on the ridge surfaces and the latter spreading over the lower level." This supposed line of marginal deposit has been traced by Buell from the point where it emerges from beneath the Kettle moraine, near the line of Dane and Greene counties, Wisconsin, southward through eastern Greene County, Wisconsin, into northeastern Stephenson County, Illinois. Quartzite bowlders have been discovered in this belt and over the country to the east to points slightly beyond Rock River, but none were found by Buell west of this belt. They are readily found as far south as the latitude of Freeport and Rockford, but farther south they are very rare, and apparently represented only by small fragments. Buell thinks it probable that the southward movement extended but little beyond a line connecting these cities, the scattering pebbles to the south being transported perhaps by water. The southward movement is thought to have been followed by a southwestward one in southern Wisconsin, with perhaps westward movement in southern Illinois, by which quartzite bowlders were carried southwest from the ledges slightly beyond the limits of the Kettle moraine. This invasion is referred to the Iowan stage of glaciation by Buell, and is correlated by him with the main loess deposition. He limits its western extension to the east border of the loess.

The interpretation made by Buell would refer the earliest or westward

[1] Bowlder trains from the outcrop of the Waterloo quartzite area, by Ira M. Buell: Trans. Wisconsin Acad. Sci., Vol. X, 1894–95, pp. 405–509.

movement to the Illinoian stage, while the southward movement is interpolated between the Illinoian and Iowan. If, therefore, this interpretation be correct, it affords no evidence of a pre-Illinoian invasion. The subject of bowlder transportation has been studied so little as yet that it may be unsafe to take the interpretation given by Buell as final, although it appears well sustained. On this question, as well as on that of the age of the conglomerate found on the borders of Rock River, further light is desirable.

Hershey has recently discussed certain silts in northwestern Illinois, which underlie the Illinoian drift, as probable representatives of a stage of glaciation preceding the Illinoian.[1] He does not, however, refer the silt deposition to a time much earlier than the Illinoian.[2] There is evidence of erosion of this silt prior to the ice invasion which deposited the Illinoian drift. It is possible that these silts may be correlated with the ferruginous glacial conglomerate along the east side of Rock River, the conglomerate being deposited by a stream and the silts by a temporary lake, though there is as yet no adequate basis for such a correlation.

SILVERIA (?) FORMATION AND OTHER SILT DEPOSITS.

In the course of the discussion of the Illinoian drift and of the Kansan till sheet, which it overlaps on the west, frequent reference has been made to the occurrence of deposits of silt beneath the Illinoian. These deposits are known to be distributed very widely beneath the Illinoian drift, but it is not known how large a combined area they cover. They appear to be present in conspicuous amount beneath many streams of northwestern Illinois, but are not often exposed to view because of their position beneath the level of the streams. They appear to be less extensively developed in western and southern Illinois, though not rare in either district. Their best development, so far as known, is along the line of valleys which were favorably situated for the development of lakes in front of the ice, valleys whose lower courses were entered by the ice sheet, while their upper courses remained for some time uncovered by the ice.

Hershey has proposed the name Silveria for deposits of this class in northwestern Illinois.[1] The necessity for a name for such deposits will

[1] Am. Jour. Sci., 4th ser., 1896, Vol. II, pp. 324–330.

[2] As Hershey uses the word Kansan for the sheet which we are discussing as the Illinoian, the reader may find it somewhat confusing to interpret his language. Hershey, however, is not at fault in the use of this term, since his paper was prepared before the name Illinoian had been introduced. He naturally inferred, in the absence of knowledge to the contrary, that the same name should be applied to the sheet outside the Iowan in northwestern Illinois as has been applied in southern Iowa.

depend upon the bearing they may have upon glacial history and their relation to each other. Should it be found that any of them bear evidence of a distinct stage of glaciation to which no name has yet been applied, or to any part of geological time not assigned a name, it would seem proper to introduce a name. But if they simply mark the deposits of small lakes of temporary character formed during an ice advance to which a name has already been applied, it would seem better to extend the name of the ice invasion to the silts. Thus we might speak of buried silts of Kansan age or of Illinoian age. The relation to the glacial deposits would then be more clearly seen than if a separate name were applied to the silts. In the case of the silts which Hershey has named Silveria there appears to be evidence that they do not connect definitely with the advancing Illinois ice lobe, for, as noted above, they seem to have suffered some erosion prior to the Illinoian ice invasion. It therefore may be necessary to retain the

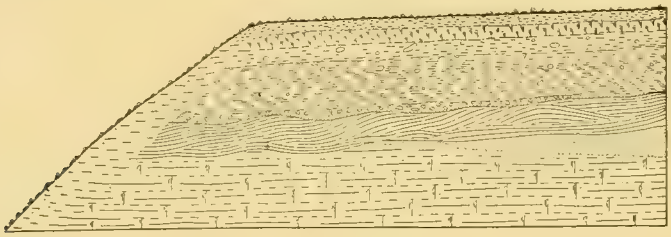


FIG. 1.—Section showing the "Silveria formation" near Freeport, Illinois; prepared by Oscar H. Hershey. *g* and *h* combined are the "Silveria."

name Silveria, but to restrict it to deposits which are clearly of similar age to those examined by Hershey. If, on examining the silts of valleys in other parts of the region covered by the Illinois lobe, it is found that a similar interval of erosion separates their deposition from that of the Illinoian drift, the name may be extended perhaps to such deposits. But if it is found that valleys contain silt deposits which immediately precede the Illinoian till sheet in date of deposition, it seems advisable to withhold the name Silveria and refer to them as the silts of the Illinoian stage. It is probable that many if not all the valleys in which the Illinoian till sheet blocked the lower course and formed the temporary lakes contain deposits of this latter class. It is likely, therefore, to be more extensive than the Silveria formation. Hershey recognized this restricted application of the name, and gives the extraglacial silts a separate place (see fig. 1).

In western Illinois, as was indicated above, there are silts which appear

to have been formed at the Kansan stage of glaciation by the blocking of valleys which had westward discharge to the Mississippi. If this be the correct interpretation, these silts can not properly be termed Silveria, for they may be much older than that formation and their relation to the Glacial series would be more clear if they were termed Kansan silts.

The Silveria formation discussed by Hershey "is a thick bed of stratified silt of a nearly uniformly dark bluish-gray color with bands often several feet in thickness which are a lighter tint." But one surface exposure has been found, and is located in a small ravine 1½ miles south of the city of Freeport, yet wells have shown its occurrence in the valleys of nearly all the streams in the Pecatonica drainage basin. At the surface exposure "the upper portion is a false-bedded, calcareous and ferruginous, light-brown fine sand and silt, and appears to represent the shore deposits of an ancient lake in which this formation was apparently laid down." Its calcareousness strongly supports the view that it is a glacial silt. Several species of small shells and also fragments of partially decayed wood have been collected by Mr. Hershey. Specimens of the shells, submitted to Dr. W. H. Dall, of the United States Geological Survey, are found to represent three different species, with fragments of still other species. These species are present in about the following proportionate numbers: *Succinea avara* 50, *Pupa blandi* 5, *Pyramidula striatella* 2. Hershey refers the occurrence of this terrestrial fauna in a deposit of lacustrine character, to the position near the shore of the lake.

This deposit appears to have considerable bulk in the valleys of Stephenson County. In a well 3 miles southwest of Freeport, in the old valley of Yellow Creek, it was penetrated to a depth of 150 feet without reaching the bottom. Hershey estimates that if spread out over the entire surface of Stephenson County, this deposit would make a uniform layer at least 14 feet in depth. He estimates the total depth of the superficial deposits of Stephenson County to be 32⅓ feet. It forms therefore nearly half the bulk of these deposits.

Above the silt which Hershey has called the Silveria formation there is another silt deposit separated from it by an erosion unconformity and a slightly developed soil. This he considers an extraglacial lake deposit formed during the advance of the ice sheet which formed the overlying till. This deposit he estimates to have an average thickness, if spread over the

entire surface of Stephenson County, of but 1 foot, or only one-fourteenth the bulk of the Silveria formation.

In the vicinity of Rock Island several exposures of silt have been found by Prof. J. A. Udden beneath the lowest deposit of till, and through his kindness the writer has been conducted to them. Whether these deposits are all of similar age, and whether they are earlier or later than the Kansan, has not been determined. They appear to be at least as old as the maximum extension of the Illinoian sheet. One of the best exposures is that made by a well at the base of the Mississippi bluff, near Thirty-sixth street, in Rock Island. The bluff back of the well carries about 40 feet of loess and several feet of till above the level of the well mouth. The exposures are not adequate to show the age of the till, though it is probably Illinoian. The section of the well, which was observed while in process of excavation both by Professor Udden and by the writer, is as follows:

Section of well near Thirty-sixth street, Rock Island, Illinois.

	Feet.
Yellow till (probably Illinoian)	5
Black muck (Yarmouth?)	1
Brown till (leached 2 or 3 feet)	7
Blue till (probably Kansan)	4
Black calcareous silt, with gasteropod fossils	8
Black muck	4
Green muck with a few local pebbles	5
Coal Measures shale.	
Total	34

Within a mile east from this exposure, in the city of Moline, a well observed by Udden reached a fossiliferous loess-like silt beneath a pebbly clay at a depth of 30 feet. The well is on the Mississippi River bottom, corner of Seventh avenue and Fifth street, Moline, at an altitude about 30 feet above the low-water mark of the river.

A ravine on the range line between sec. 7, T. 17 N., R. 1 W., and sec. 12, T. 17 N., R. 2 W., exposes the following section:

Section of ravine on range line between sec. 7, T. 17 N., R. 1 W., and sec. 12, T. 17 N., R. 2 W.

	Feet.
Loess	45
Black soil	2
Yellowish-brown till	12
Loess-like silt, containing fossils	several feet
Coal Measures sandstone.	

Another exposure occurs in the east bluff of the Mississippi near the line of Rock Island and Mercer counties and has the following section:

Section of ravine near the line of Rock Island and Mercer counties, Illinois.

	Feet.
Loess	25
Black soil	2–3
Till, mainly of blue color	90
Loess-like silt, very fossiliferous	12
Total	130

The bottom of the lower loess was not reached by this ravine. This deposit differs from the surface loess in containing a large number of nodules and tubes of partially solidified material. These have a yellowish color and are largely due to the presence of iron oxide.

Specimens of fossils have been collected by Udden from these buried loess-like silts in Rock Island County as well as from surface loess and submitted to Dr. W. H. Dall and his assistant, Mr. C. T. Simpson, for examination. The buried silt deposits are found to contain a larger proportion of *Helicina occulta* than the surface loess and a smaller proportion of *Succinea avara*. These two species are the most abundant ones in all the deposits, whether surface loess or buried silt. With the exception of the exposure of the east bluff of the Mississippi, the only additional fossils found in the buried silt are *Pyramidula striatella* and *Pupa alticola*. The latter species is now confined to the Rocky Mountain region. The specimens collected from the ravine in the east bluff of the Mississippi, near the line of Rock Island and Mercer counties, contain a greater variety, as follows:

Helicina occulta Say; very abundant.
Helicodiscus lineatus Say.
Limnæa humilis Say (variety).
Pyramidula perspectiva Say.
Pyramidula striatella Anth.
Pupa armifera Say.
Strobilops labyrinthica Say.
Succinea avara Say; less abundant than in surface loess.
Succinea luteola Gould.
Vitrea arborea Say?

The origin and relations of the buried loess-like silts of Rock Island County remain to be determined. Whether they are the deposit of an

extraglacial lake formed in valleys in front of the advancing ice sheet, or, like the surface loess, have a wider distribution less clearly connected with the ice invasion, is not at present known. They may be widely distributed beneath the Illinoian sheet in western Illinois. In texture and general appearance these deposits are very similar to the surface loess. They are apparently not so compact as the laminated silts of northwestern Illinois, described by Hershey under the name Silveria formation.

The deposits of laminated clay with sand partings, found beneath the till in central Adams County, Illinois, have already been discussed as probable products of an obstruction of an eastern tributary of the Mississippi by the Kansan invasion of the Keewatin ice sheet. It is probable that similar deposits fill the valleys of other eastern tributaries of the Mississippi in western Illinois, though as yet none have been observed. The date of these laminated clays, compared with that of the buried silt of Rock Island County, or of the Silveria formation of Stephenson County, is not known.

The silt beneath the till at Pana, noted above, is so much older than the overlying till that it can scarcely be considered an extraglacial lacustrine deposit formed during the ice advance which deposited the till. Its origin and date are not determined.

In the reports of the geology of Illinois there appear several instances of the occurrence of a plastic blue clay, or "blue mud," below the till in the vicinity of the glacial boundary in southern Illinois.[1] This blue material appears to be a silt deposit stained by humus. It often contains much wood and other organic matter. The writer has not been successful in finding an exposure and can not pass an opinion upon the character or the origin of the deposit. It is probable that valleys in that region which were obstructed by the advancing ice sheet were filled to some extent by silt, but since the deposit in question contains wood and other vegetal material it apparently antedated the till by a considerable interval, though it is possible that the accumulation of wood and organic matter is due to the introduction of this material by currents of water during the silt deposition, and not by the growth of vegetation on the silt after the completion of the deposition.

A detailed section of the material penetrated by the Isabella Thompson

[1] Geol. Illinois, Vol. I, pp. 299, 300, 316; Vol. III, pp. 75, 86, 87, 103.

coal shaft near Sparta in eastern Randolph County, has been published by Prof. J. M. Nickles.[1] The Pleistocene deposits are as follows:

Section of Pleistocene beds penetrated by the Isabella Thompson coal shaft near Sparta, Illinois.

	Feet.
Soil and clay	3
Yellow clay	17
Blue clay	3
Quicksand	4
Silt	2
Gravel	4
Silt	3½
Sand and gravel	6½
Drab or mouse-colored silt	11
Concrete or hardpan	4
Fine gray sand	6
Sand and clay mixed	6½
Silt	2½
Bowlder clay	6½
Fine gravel	4
Bowlder clay	1¾
Laminated clay, containing wood	5
Total drift	90

In this section there appears to have been an alternation of glacial and lacustrine deposition without distinct evidence of long interruption. The laminated clay at the base of the series contains a large amount of wood, specimens of which have been sent to the writer by Professor Nickles, but which await specific identification.

Borings for coal and water in the Big Muddy Valley in the vicinity of Murphysboro usually penetrate a large amount of sand. As this valley does not appear to have been obstructed by the ice invasion the sand can not be referred with any certainty to lacustrine conditions. It seems more probable that it is an indicator of the weakness of the currents of the stream.

The tributaries of the Wabash in southeastern Illinois are usually filled with sand or silt, and these open southward in such manner as to avoid obstruction by the advancing ice sheet. The filling probably may be taken as an index of the weakness of the currents of the stream just before the ice invasion. It may be remarked in this connection that the filling of the valleys of southern Illinois apparently opposes the somewhat popular hypothesis that there was a period of high elevation and vigorous

[1] Final report Illinois Board World's Fair Commissioners, 1893, pp. 200, 201.

stream action in this part of the Mississippi Basin just before the first ice invasion.

The character of the deposits beneath the till in the valleys of southwestern Indiana has not received attention, for that region has been given only a hasty reconnaissance. The Wabash Valley is filled to considerable depth with sand and fine gravel, but this may be in large part derived from the Wisconsin glacial drainage. Its rock floor stands 75 to 100 feet below the present stream at the points where tested by borings. The tributaries show a correspondingly low rock floor, but their filling in the district outside the Wisconsin drift is not so coarse as that along the Wabash.

CHAPTER V.

THE YARMOUTH SOIL AND WEATHERED ZONE.

The occurrence of a definite soil and weathered zone between the overlapping portions of the Illinoian and Kansan till sheets has been so fully set forth in the discussion of the Illinoian drift border that but few further remarks seem necessary. The name Yarmouth, as above indicated, is from the village in Des Moines County, Iowa, where the evidence of a prolonged interval between the till sheets, now known as Kansan and Illinoian, was first recognized. It remains to be determined whether the occasional instances of soil reported to occur between sheets of till in portions of the Illinoian area east of the limits of the Keewatin ice sheet are to be referred to the Yarmouth interglacial stage. Further light is also necessary to determine whether all instances of buried soils within the region of overlap of Illinoian upon Kansan till are to be referred to the Yarmouth stage. For example, the buried soil in the gas belt west of Letts may prove to be of earlier date than the Yarmouth, though it seems quite probable, as above noted, that it is found in a valley which had been cut in the Kansan drift prior to the Illinoian invasion.

WEATHERING OF THE BURIED KANSAN DRIFT.

Among the several evidences of a long interval between the Kansan and Illinoian invasion, that of weathering is the most common and perhaps the most decisive. As shown in the sections given above, there is found to have been a general leaching of the sheet of calcareous Kansan till to a depth of 4 to 6 feet prior to the deposition of the Illinoian sheet of drift. Accompanying the leaching the upper portion of the Kansan drift was weathered to a brown and in places reddish-brown color. The brown color extends much below the limits of the leaching, there being not a few instances in which it extends to a depth of 25 or 30 feet, and it is rarely less than 12 to 15 feet. The reddish-brown stain usually extends only to a depth of 2

or 3 feet from the surface. The Kansan till, as noted above, is commonly characterized by vertical fissures and shows a tendency to fracture in rectangular blocks. Along the lines of the fissures the brown stain often extends some distance into the blue or unoxidized portion of the sheet, thus extending the limits of oxidation still lower than the general zone of oxidation. As previously stated, the amount of leaching and oxidation at the Yarmouth stage appears to be about as great as in all post-Illinoian time.

There are, as above noted, places where the Illinoian till rests directly upon an unleached Kansan, but in such places the oxidation and vertical fissuring are present to testify to the changes effected in the Kansan sheet. The absence of a leached zone at the top of the Kansan in such places is readily accounted for through removal by the Illinoian ice sheet. It is perhaps more remarkable that the leached zone is so well preserved than that it should have been occasionally removed by the Illinoian ice invasion.

BURIED SOIL, PEAT, ETC.

The accumulation of beds of peat at the surface of the Kansan drift, prior to the Illinoian ice invasion, constitutes as impressive an evidence of a prolonged interval as the leached and reddened surface. In the Yarmouth section the peat has a depth of 15 feet while underlying beds of sandy clay, and sand carrying bits of wood, probably also to be classified as interglacial, extend the depth of the Yarmouth deposits to 43 feet. Buried soil of black color and beds of peat have attracted the attention of well diggers in nearly every township of the region of overlap in southeastern Iowa, and specimens of the peat obtained from wells are preserved at many of the farm houses. Along the border of the Illinoian the soil is usually found at about the general level of the upland portion of the Kansan drift surface and may be referred with confidence to the Yarmouth stage, but occasionally it occurs below that level. In such instances, so far as the writer is aware, no soil has been noted at a level corresponding to the upland surface of the Kansan. The presumption is that the soil occurs in interglacial valleys which had been cut into the Kansan prior to the Illinoian invasion, and that the entire till deposit above the soil is Illinoian. The erosion thus indicated commonly shows a depth of less than 50 feet and harmonizes with the depth of pre-Illinoian valley erosion of the drift outside the limits of the Illinoian drift. There is, however, an occasional example of the occurrence

of a buried soil in the district west of the limits of the Illinoian, either underneath or within the Kansan drift. This feature makes it necessary to leave open the question of the age of buried soils within the Illinoian area which occur at a level below the general elevation of the outlying Kansan drift.

EROSION OF THE KANSAN DRIFT SHEET.

The pre-Illinoian erosion of the Kansan till sheet is a third evidence of the great length of the Yarmouth interglacial stage. Such erosion, as just noted, is suggested within the limits of the Illinoian by the occurrence of a buried soil below the general level of the Kansan drift surface. But evidence may be found in the portion of the Kansan drift lying outside the limits of the Illinoian which is not at all open to question. The evidence first to attract notice was that of the relative degrees of erosion displayed by the Illinoian and Kansan drift sheets. Prior to the discovery of the extension of the Illinois lobe into southeastern Iowa it had been noted by Chamberlin, as well as by the writer, that southern Iowa presents a more eroded appearance than western Illinois and the southeastern counties of Iowa, and the matter was discussed as a remarkable feature. In the district outside the limits of the Illinoian the original drift plain is preserved only in narrow strips along divides, estimated to comprise scarcely one-fourth of the surface, while in the district covered by the Illinoian drift the remnants are far more extensive, comprising apparently more than half the surface. The branching of drainage lines is also carried to markedly greater maturity in the Kansan than in the Illinoian drift.

Definite means for determining the amount of pre-Illinoian erosion of the Kansan is afforded by a study of the valleys in Kansan drift which connect with the abandoned valley of the Mississippi, which was occupied at the Illinoian invasion. These embrace the valleys of West Crooked Creek, Skunk River, and Big Cedar Creek. Valleys farther north have generally been greatly modified by the Iowan invasion, and hence do not furnish good illustrations. It is found that the three valleys just noted have been cut at their points of connection with the abandoned valley to a depth of about 50 feet below neighboring uplands and to widths of about three-fourths of a mile, 1½ miles, and 1 mile, respectively, at the time the Mississippi was occupying this abandoned channel, i. e., at the Illinoian stage of glaciation. This width is two or three times that of the inner valleys, which

are now cut far below the level of the pre-Illinoian valleys, but represents nearly as much removal of material, and the removal was probably effected at a lower gradient, i. e., under less favorable conditions than are now afforded. In this connection it should be noted that no evidence has been found that the gradient of the streams was increased until after the Iowan stage of glaciation. The inner valleys represent, therefore, post-Iowan rather than post-Illinoian excavation. But this fact does not apparently set aside the estimate given above, for if the pre-Illinoian valley excavation had not reached the level of the channel opened by the Mississippi at the Illinoian stage of glaciation, that valley would have furnished a more direct and presumably more favorable line of discharge for all these streams than their present line. The features along the present line of discharge for the three streams under consideration (eastward through Skunk River) strongly support the view that a pre-Illinoian valley was formed in the lower course of Skunk River. A broad terrace borders the portion of the valley below the point where Skunk River crosses the abandoned valley at Rome, which stands sufficiently low to have afforded a line of discharge for the portion of the valley west of the abandoned channel. This would have been blocked at the Illinoian ice invasion, but not necessarily concealed or greatly filled by Illinoian drift. Upon the withdrawal of the ice, if it chanced to stand slightly lower than the Illinoian course of drainage, it would receive the post-Illinoian drainage and become the line of a reestablished stream.

There is near the mouth of Skunk River an exceptionally clear illustration of the work of that stream in the Yarmouth interglacial stage. By reference to fig. 4 it will be seen that a valley or depression turns away from Skunk River at Augusta and leads southward to Lost Creek. This valley is more than a mile in width and 30 feet or more in depth, and is excavated in the Kansan till. Evidently it was opened by Skunk River after the Kansan stage of glaciation and before the Illinoian stage. Whether it carried the whole or only a part of the stream is not yet known. The northern end has received only a thin coating of Illinoian drift. The southern end received a sufficiently heavy deposit of that drift to prevent its subsequent use as a drainage line. Since the Illinoian stage of glaciation the entire drainage of the river has been directly eastward into the Mississippi. Low swells of Illinoian drift occupy the south end of the

valley and show clearly that there has been no valley excavation there since they were formed.

The valley of Lost Creek in Lee County, Iowa (see fig. 4), though lying wholly within the limits of the Illinoian drift, bears evidence of having been occupied and largely excavated by a pre-Illinoian stream. It presents a shallow trough cut in Kansan drift, which is covered, but not greatly concealed, by Illinoian drift. Low swells of till formed at the Illinoian invasion occur on its slopes and bottom, thus proving its pre-Illinoian excavation. This valley is about one-half mile in width and 30 to 50 feet in depth, and holds this size nearly up to the head, which is found in the marginal ridge of Illinoian drift. It seems probable that prior to the Illinoian invasion its drainage basin was much more extensive than at present. This affords an illustration of a partially reestablished stream. This valley and that of the lower course of Skunk River are exceptional, for as a rule the pre-Illinoian tributaries of the Mississippi were so completely filled at the Illinoian invasion that the post-Illinoian drainage was opened along new lines. It is probable that the portion of the Mississippi between Muscatine and Fort Madison, Iowa, is reestablished along a pre-Illinoian and also pre-Glacial line.

ORGANIC REMAINS.

As yet no specific identifications of the wood and smaller plants found at the Yarmouth horizon have been made, unless some of those reported by McGee from northeastern Iowa have this horizon. The wood appears on a superficial examination to be coniferous and largely red cedar. It is planned to have careful examinations made in the near future to ascertain the bearing the plants may have on the climate at the Yarmouth interglacial stage. It should be considered, however, that the plants found in the peat were presumably living just before the culmination of the Illinoian invasion, and may not afford a true index of the interglacial stage; for a general lowering of temperature probably preceded as well as accompanied the culmination of the ice sheet. Possibly a deposit will yet be found in which plant remains occur which were buried in the middle part of the interglacial period. The specimens of wood noted in the clay beneath the bed of peat at Yarmouth may have been buried at a sufficiently early date to be unaffected by the Illinoian glaciation. Unfortunately no specimens of that wood are now available.

The animal remains (rabbit and skunk, see p. 42) found in the peat at Yarmouth show a remarkable state of preservation, the marrow of the bones being still preserved, as noted in the examination by Dr. F. W. True. This is perhaps no more remarkable than the state of preservation of some specimens of the wood from the same horizon. Several of the wood specimens have been found to take fire as readily as the wood from our living forests. In not a few cases within the writer's notice leaves of grasses or sedges have been found in a fair state of preservation. Instances of the occurrence of leaves of oak or other deciduous trees have been reported to the writer from the Yarmouth horizon, but none have come under his personal observation. The character of the life of this interglacial stage is a field promising much of interest, but which as yet is scarcely at all developed.

CHAPTER VI.

THE SANGAMON SOIL AND WEATHERED ZONE.

Between the disappearance of the Illinoian ice sheet and the deposition of the Iowan till and loess there occurred an interval of deglaciation about as marked as that between the Kansan and Illinoian stages of glaciation, a period marked by leaching and oxidation of the Illinoian drift, of peat and soil accumulation, and of erosion. This interval was long since brought to notice by Prof. A. H. Worthen in his report on Sangamon County, Illinois.[1] For this reason, and because of the conspicuous development in the Sangamon drainage basin, it seems appropriate to name it the Sangamon interglacial stage. This name was suggested by the writer in a paper presented before the Iowa Academy of Sciences in December, 1897.

The following section, published by Worthen, was furnished him by a well digger, Joseph Mitchell, who had dug many wells in the northwest part of Sangamon County and in the adjoining portion of Menard County:[2]

Generalized section of wells northwest of Springfield, Illinois.

	Feet.
Soil	1– 2
Yellow clay	3
Whitish (gray ?) jointed clay, with shells	5– 8
Black muck with fragments of wood	3– 8
Bluish colored bowlder clay	8–10
Gray hardpan (very hard)	2
Soft blue clay, without bowlders	20–40

This section represents the formations beneath the upland plain near the western edge of the Sangamon watershed at an altitude 200 feet or more above the level of the mouth of the Sangamon. Worthen remarks

[1] Geol. of Illinois, Vol. V, 1873, pp. 306-319. [2] Op. cit., p. 307.

that the fossiliferous clay of the section is undoubtedly loess. He calls attention also to the prevalence of conditions suitable for the growth of an arboreal vegetation prior to the deposition of the loess.

In the section just given, the black soil appears to be the representative of the Sangamon interglacial stage. But this interglacial stage, like the Yarmouth stage, is often represented by a leached and slightly reddened till surface, unaccompanied by black muck. These two phases seem to be mutually exclusive, there being but slight reddening of the till surface where the black muck is present, or but slight accumulations of black muck where the reddening of the till is pronounced. The black muck is developed in portions of the uplands where the surface is very level and conditions for drainage are defective, while the reddened soil is developed on the more undulatory tracts, where a fair condition of drainage probably existed. The black muck phase is common in the Sangamon Basin, and also in the northern part of the white clay district of southern Illinois, and southwestern Indiana just outside the limits of the Shelbyville drift sheet. In western Illinois and southeastern Iowa it has a more restricted development, for the surface there is generally more elevated and better situated for the development of drainage lines than in the districts first mentioned. In southern Illinois and southwestern Indiana and throughout much of western and northwestern Illinois, the reddened till surface is a conspicuous feature.

In certain areas an alternation of sand with peaty beds has been found between the Iowan loess and the Illinoian till. This phase is apparently restricted to the borders of valleys where stream action has probably been influential but with intermittent activity, the sand being deposited by the streams, while the peat was accumulated at times when the streams failed to cover the land.

The accompanying views, Pl. X, *A* and *B*, taken in cuttings along the Santa Fe Railway in eastern Knox County, Illinois, show a dark soil (b) at the junction of the loess (a) and Illinoian till (c). In the exposures seen in these views, acid tests show the till to have been leached to a depth of about 4 feet below the dark-colored soil. The overlying loess is calcareous at base. The leaching, therefore, took place prior to the loess deposition in connection with the development of the soil. The depth of leaching noted

A. NEAR VIEW OF SANGAMON SOIL IN KNOX COUNTY, ILLINOIS.

(*a*) Loess, partly eroded, 4 feet; (*b*) Sangamon soil, 1 foot; (*c*) Illinoian drift, 4 feet.

B. MORE DISTANT VIEW OF SANGAMON SOIL IN KNOX COUNTY, ILLINOIS.

(*a*) Loess, 12 feet; (*b*) Sangamon soil, 2 feet; (*c*) Illinoian drift, 40 feet.

in this railway cutting represents about the average depth found in the interior portions of the district covered by the Illinoian drift. Along the borders of the drift, as previously noted, the Illinoian till is, in places, noncalcareous throughout its entire depth, and seems to be made up largely of the leached portion of the Kansan drift which it had overridden. Some care must be exercised, therefore, in deciding upon the amount of leaching which has taken place since the Illinoian ice sheet disappeared.

In northern Cumberland County, Illinois, a short distance north of Greenup, Professor Chamberlin and the writer examined exposures of the Sangamon soil in which branching root-like extensions of the soil penetrate several inches into the underlying subsoil. These are thought to mark the former presence of forests on that soil.

In a few places peat beds of considerable depth have been found at this soil horizon. Some of the best instances occur a short distance west of the region in which the section reported by Worthen is found. The coal shaft at Ashland, Illinois, near the line of Sangamon and Cass counties, shows the following series of drift beds:

Section of the drift beds in a coal shaft at Ashland, Illinois.

	Feet.
Black soil	1½
Loess of yellow color	9
Loess of blue color	2
Peat and black sandy slush	22
Bluish gummy clay	20
Yellow till	30
Total drift	85

At the air shaft sand was found beneath the peat in the place of the blue gummy clay. At Virginia, Illinois, a well made by Mr. Oldridge entered a bed of peat at the base of the loess at about 15 feet and continued in it to a depth of 28 feet, beneath which a blue clay was entered.

An instance of the occurrence of animal remains in the basal portion of the loess, immediately above a deposit of peat, probably Sangamon, was long since brought to notice by Mr. Pratt, of Davenport.[1] In a railway cutting made by the Chicago, Rock Island and Pacific Company, in the

[1] Proc. Davenport Acad. Sci., 1876, p. 96, Pl. XXXII. See also Geol. of Iowa, by C. A. White, Vol. I, 1870, p. 119.

west part of Davenport, Iowa, the following beds are exposed, as reported by Mr. Pratt, who examined the exposure while the excavation was fresh:

Section in railway cutting near Davenport, Iowa.

	Feet.
1. Ordinary prairie soil, altitude 167 feet above Mississippi River	1
2. Loess, iron stained and distinctly laminated with laminæ curved and in places interbedded with thin layers of sand; the deposit also contains small calcareous nodules and shells of the genera Succinea, Helicina, and Pupa	20
3. Bluish-gray clay, containing a few shells like those of No. 2; a tusk, several teeth, and other portions of *Elephas primigenius* (?) were found just at the junction between Nos. 2 and 3	3–5
4. Bed of brown peat in which the peat moss, *Hypnum aduncum*, was sufficiently well preserved to be identified; quantities of much decomposed coniferous wood were also distributed through this bed	1
5. Dark-brown soil, resembling the peat, but more decomposed	2
6. Blue clay, very tenacious, containing sand, gravel, and small bowlders, many of them distinctly glacier scratched, extending beneath base of cutting.	

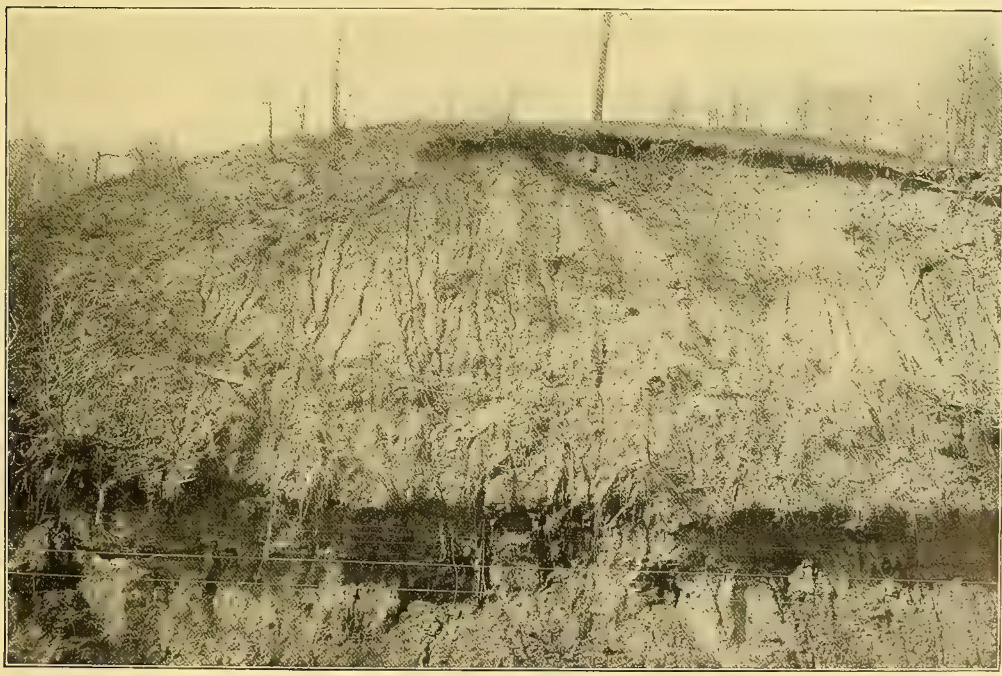
The peat bed, with its associated soil and silts, is reported to have been exposed for a distance of 30 or 40 rods. Concerning it Dr. C. A. White remarks:[2] "This deposit is quite remarkable in many respects; in none more so perhaps than in the fact that the bed of peat rests upon a bed of clayey silt and is in turn covered by a similar but much deeper one, these varying conditions evidently having been produced by the shiftings of the adjacent and then sluggish river in that very early period of its postglacial history."

The Sangamon soil has been exposed by some of the streams within the limits of the Wisconsin drift, notably on the Embarras and Kaskaskia rivers and tributaries of the Illinois. It is found below loess or white clay, which in turn lies beneath the till of the Wisconsin drift. Two excellent exposures on Farm Creek, east of Peoria, Illinois, are shown in Pl. XI, figs. *A* and *B*. In the first (*A*) the soil is not shown, but there is a deeply leached and weathered zone at the top of the Illinoian. In the second (*B*) there is a bed of peat resting upon silt which bears some resemblance to the overlying Iowan loess in texture, but is not so calcareous and is of a deeper brown color. Whether it is similar in origin to the loess can scarcely be decided. The writer also is inclined to question whether the silt below peat in the Davenport section just described should be referred to the Iowan loess. Beneath the silt which underlies the peat shown in fig. *B* there is Illinoian till, and this is leached to a depth of 3 to 4 feet. This section

[2] Op. cit., p. 120.

A. EXPOSURE ON FARM CREEK, 7 MILES EAST OF PEORIA, ILLINOIS.

(*a*) Bloomington gravel terrace, 8 feet; (*b*) Shelbyville till sheet, 14 feet; (*c*) Iowan loess, 10 feet; (*d*) Illinoian till, 30 feet. (View taken by Dr. Samuel Calvin, May, 1898.)



B. EXPOSURE IN A RAILWAY CUTTING ON THE TOLEDO, PEORIA AND WESTERN RAILWAY, 7 MILES EAST OF PEORIA, ILLINOIS.

(*a*) Bloomington gravel and cobble on slope, 6 feet; (*b*) Shelbyville till sheet, 8 feet; (*c*) Iowan loess, 6 feet; (*d*) Sangamon peat bed, 3 to 5 feet; (*e*) Silt below peat, 2 to 5 feet. Below the silt there is Illinoian till leached and weathered at top, 4 feet, beneath which it is calcareous. (View taken by Dr. Samuel Calvin, May, 1898.)

seems to indicate that for a time after the Illinoian sheet was exposed to atmospheric action the drainage conditions were good, but that subsequently they became imperfect and the peat was formed. The possible relationship between the lower silt and the gumbo of the Mississippi Basin is discussed in connection with the latter deposit (p. 32).

The wood found in association with the Sangamon soil and peat, like that of the Yarmouth, appears to be largely coniferous. Wherever identifications have been attempted such woods have been found to occur, and specimens not critically examined have the aspect of the coniferous rather than the deciduous varieties of wood. The aspect of the flora is decidedly boreal. However, as noted in connection with the discussion of the vegetation found in the Yarmouth soil, it is necessary to guard against the inference that the vegetal remains preserved in the peat and mucky portions of the soil furnish an index of the climatic conditions throughout the entire interglacial stage. They pertain only to the close of that stage when glacial conditions were being inaugurated, and may have an aspect very different from that of plants which grew in the midst of an interglacial stage.

Slight exposures of the Sangamon soil and weathered zone are to be seen on nearly every hillside within the limits of the Illinoian drift where erosion has opened a fresh exposure low enough to reach the base of the loess. A few exposures have been found within the limits of the Iowan till, but such exposures are far less common than beneath the Iowan loess.

Several excellent exposures of the Sangamon soil have been made by railway companies at points where the overlying loess has been stripped off to obtain a filling for the railway track. For example, along the Vandalia Railway, a few miles west of Marshall, in Clark County, Illinois, an area of more than an acre has been stripped of the loess, leaving the black mucky Sangamon soil at the base. A similar exposure, though less extensive, is found at West Point, Iowa. The presence of the black muck here seems somewhat remarkable, inasmuch as it occupies the crest of the marginal ridge of the Illinoian drift. The upper 6 or 8 inches is a deep-black color, beneath which there is a deposit of gray gumbo 2 or 3 feet in thickness, capping the Illinoian till. Extensive exposures of black muck below the loess have been made by the Chicago, Burlington and Northern Railway at the crossing of Johnson Creek, about 4 miles south of Mount

Carroll, Illinois. At this place the loess has a thickness of nearly 20 feet. The till beneath this buried soil has been leached as far down as exposures extend, 3 to 4 feet. Still another extensive exposure of the soil is found in the pit of the Brick and Tile Works at Galva, Illinois. The loess, to a depth of 15 feet, is used in the manufacture of the brick and tile, beneath which is a black mucky soil about 1 foot in depth, which caps the Illinoian till sheet. In this soil a log about 1 foot in diameter and several feet in length was found embedded.

The conditions for erosion during the Sangamon interglacial stage seem to have been decidedly less favorable than in the Yarmouth stage. The streams apparently were so broad and sluggish as to cut only shallow valleys, and these are seldom sharply outlined. The general absence of well-defined valleys beneath the Iowan loess on the area occupied by the Illinoian drift sheet, when taken in connection with their conspicuousness in the Kansan drift, is liable to give the impression that only a brief interval separates the Illinoian from the Iowan glacial stage. But if interpretations are made from the leaching, and depth of peat and muck accumulation during the Sangamon interglacial stage, there are found indications of a period which compares favorably in length with the Yarmouth interglacial stage. The depth and degree of oxidation of the Illinoian, when compared with the Iowan, are also impressive evidence in favor of a wide separation in the dates of deposition of the two deposits. The amount of erosion, therefore, appears to be a poor index of the length of the interglacial period, though if low altitude and slack drainage be assumed it easily harmonizes with the evidence of a long interval denoted by the other features of the drift. In discussing this matter with the several glacialists who are familiar with the deposits representative of each glacial stage the writer finds them unanimous in considering the Illinoian drift a much older deposit than the Iowan. There is some difference of opinion as to whether the Sangamon or the Yarmouth is the longer interglacial interval. The writer inclines to the opinion that the Yarmouth is the longer interval.

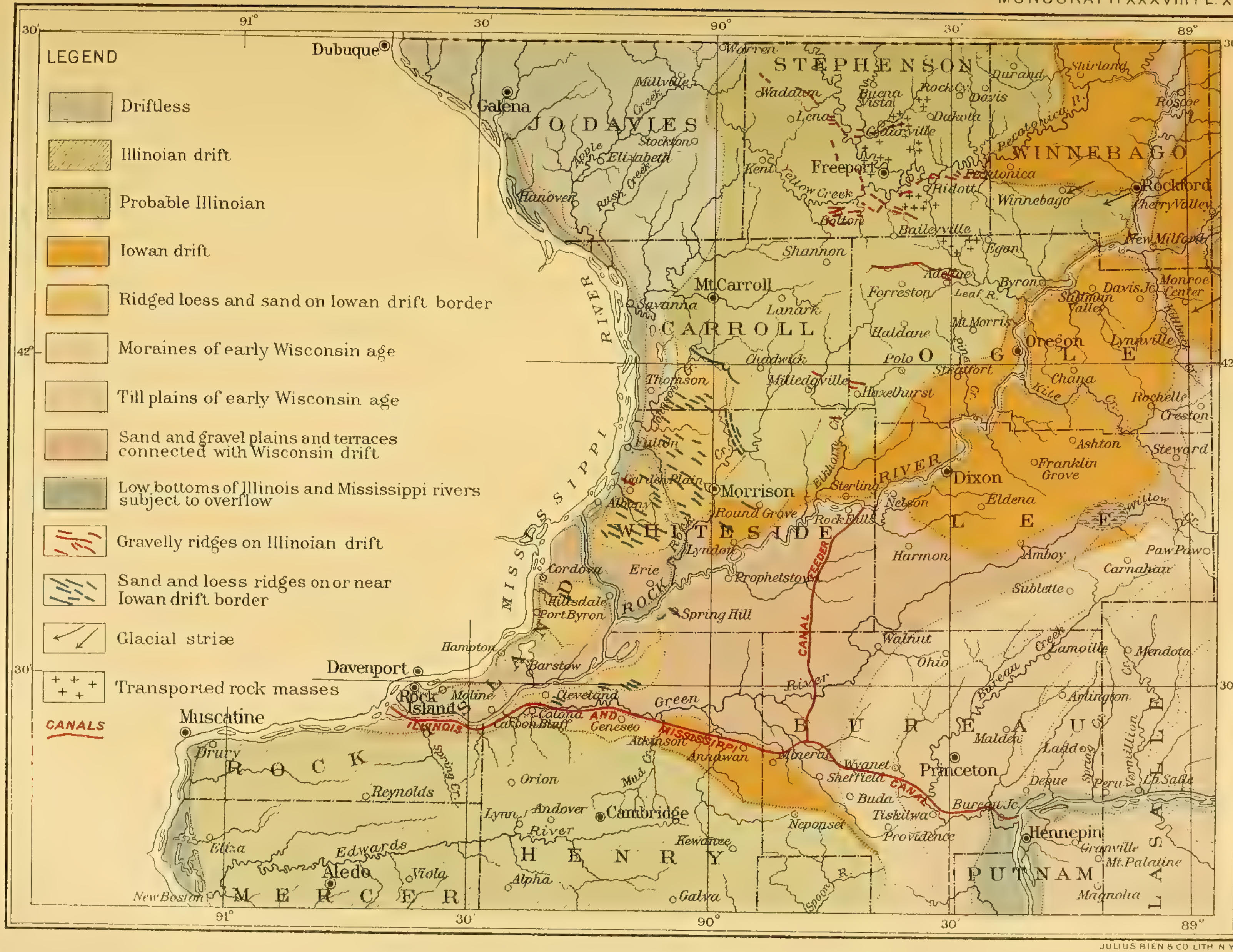
PRE-GLACIAL DRAINAGE
OF
NORTHWESTERN ILLINOIS

BY FRANK LEVERETT

1898.

Note: The pre-glacial drainage is completely obscured in the southern part of the district shown on this map. The courses of drainage lines across the Green River basin are conjectural, for the divides as well as valleys are concealed. The present Rock River crosses cols at A.B.C. and probably at D and E.

Scale
5 0 5 10 15 MILES



GLACIAL MAP OF NORTHWESTERN ILLINOIS

BY FRANK LEVERETT.

Scale

5 0 5 10 15 MILES

1898

CHAPTER VII.

THE IOWAN DRIFT SHEET AND ASSOCIATED DEPOSITS.

THE IOWAN SHEET OF THE ILLINOIS LOBE.

The sheet of drift to which the name Iowan is here applied is referred to the Iowan stage of glaciation, not because of direct connection with the Iowan drift of eastern Iowa, but because of an apparent similarity with the Iowan drift of eastern Iowa in its connection with the great sheet of loess in the Mississippi Basin. As shown below, the loess overlaps this drift sheet only a short distance, and was deposited apparently while the ice sheet was melting away, there being no clear evidence of an exposure of its till to protracted atmospheric action prior to the deposition of the loess.

DISTRIBUTION.

The Iowan sheet of the Illinois lobe was formed by a southwestward ice movement over northern Illinois. Its western border has been traced in some detail by Mr. Oscar Hershey, through Winnebago, Ogle, Lee, and Whiteside counties. The writer had previously noted the occurrence of this drift in Winnebago, Ogle, and Lee counties, but had not attempted a precise mapping of its western border.

The border is found to enter Illinois from Wisconsin at the valley of Sugar River, about 12 miles west of Beloit. It follows this valley southward to the Pecatonica Valley and thence, as shown in Pl. XII, passes up the Pecatonica about to the line of Winnebago and Stephenson counties, where it crosses to the south side of the river and returns eastward to the city of Rockford, thus forming a narrow lobe at the Pecatonica Basin, having a protrusion of about 12 miles and a width no greater than its length. This lobe is called the Pecatonica lobe, since it occupies a low district or basin drained by the Pecatonica River.

Below Rockford the border is found to follow nearly the course of Rock River to the vicinity of Oregon. Here Hershey makes a division of the drift margin. The outer margin passes westward to Polo. The inner margin passes southward along or near Rock River to the vicinity of Dixon. It there crosses the river in a westward course and follows the north border of a lowland tract which extends a few miles back from Rock River. North of Sterling it joins the outer margin. Hershey's tracing of the outer margin was carried no farther than Polo, but the writer has examined the district south and west from Polo, and also the portion of this margin from Polo eastward to Rock River.

Eastward from Polo there is a definite border, characterized by low swells of till, among which are saucer-like depressions, giving the surface a much fresher appearance than that of the older sheet which occupies the district to the north and west. At Polo the margin appears to swing southward and follow the east border of the Elkhorn Creek Basin into Whiteside County. The border is not so definite here, however, as east of Polo, there being only a few till swells and occasional basins in the outer part of the drift sheet. This line connects in eastern Whiteside County, about 5 miles northeast of Sterling, with the inner margin traced by Hershey. Hershey's chief criterion in mapping the inner border is a change in the character of the till, such as characterizes the margin farther north, that to the east of it being more sandy than that to the west and displaying a pink tint not noted to the west. The portion between the inner and outer margins has a more compact texture than the remainder of the Iowan drift sheet. The cause for this difference is not yet apparent.

The margin lies north of Rock River at least as far west as Rock Island Junction. There is a small area on the north side of Rock River, west from Rock Island Junction, in which a sheet of drift with fresher aspect than the Illinoian is found. It is apparently confined to a lowland tract whose north border is followed approximately by the Chicago and Northwestern Railroad from Round Grove to Morrison, and whose west border lies along Rock Creek from Morrison south to the valley of Rock River. To the north and west of this lowland there is a heavy deposit of loess which largely conceals the underlying deposits, but the lowland has only a thin coating of loess except in a few ridges resembling the paha of eastern Iowa. Such an extension of the lobe as would be necessary to carry it to Morrison seems

rather questionable, especially since it calls for a movement north of west. It is, however, not so narrow a tongue as appears to have been thrust westward into the Pecatonica Basin, and projects but 4 or 5 miles beyond a regular border in line with that in eastern Whiteside County. The difficulties seem scarcely as great as would be involved in an invasion of ice from eastern Iowa into this district at the Iowan stage of glaciation. There are, however, in northwestern Whiteside and southwestern Carroll counties features which raise the suspicion that ice from the Iowa side may have crossed into that district in the Iowan stage of glaciation and extended as far east as the meridian of Morrison. It becomes necessary, therefore, to consider the question of an extension of the Iowan ice sheet from Iowa southeastward into this tract. This question is considered later (p. 144).

It is difficult to determine the position of the border of this ice sheet south from Rock River, since there is a broad area occupying the interval between Rock and Green rivers, in which heavy deposits of sand occur. Exposures of fresh-looking till north of Spring Hill seem to be of Iowan age. South from the Green River sand deposits there is a narrow tract of low country extending eastward from Geneseo to the vicinity of Sheffield, in which there is very little sand, and also very little loess compared with the covering on the higher districts to the south, and which may prove to have been occupied by the Illinois lobe of the Iowan ice sheet during the loess deposition. Its south border is within 2 or 3 miles south of the Chicago, Rock Island and Pacific Railway throughout the interval between Geneseo and Sheffield, and is marked by a bluff-like rise of 40 to 60 feet to a belt of heavy loess. Immediately east of Sheffield the outer moraine of the Wisconsin drift sets in, and no drift attributable to the Iowan invasion has been recognized outside its limits in districts to the south. There appears, therefore, to be striking similarity between this lobe of Iowan age and that which occupied eastern Iowa. They each show at the north remarkable protrusions, extending in both cases nearly to the borders of the Driftless Area. Their margins also are strikingly different in outline from those of preceding and succeeding sheets in the same districts. The east Iowan sheet has been found to extend only about to the latitude of Rock Island and Muscatine, and possibly the lobe which we are considering extended no farther south. There are, however, till deposits in eastern Illinois, as far south as Iroquois County, which are suspected to be of Iowan age, as indicated below.

TOPOGRAPHIC EXPRESSION.

At several places along the border of this drift sheet in Winnebago, Ogle, and Whiteside counties low swells and ridges appear, but they are seldom more than 10 or 15 feet in height. These serve, however, to give definiteness to the margin, although they are very inconspicuous features. In most cases the low swells are plainly independent of drainage erosion, there being instances in which they pass across a valley which had been formed in the earlier drift, dotting its slopes and bottoms and passing onward over the bordering uplands in utter disregard of the drainage lines. Such knolls may be seen near the mouth of Leaf River in Ogle County, and also on the borders of the Pecatonica in Winnebago County. Along portions of the border the separation of the erosion features from the drift aggregations produced by this ice invasion is somewhat difficult. Such is the case on the borders of the lowland tract north and west from Sterling, where the undulations are probably in part due to drainage erosion. A similar difficulty is experienced in the narrow belt of lowland east from Geneseo. There are present, however, in both these districts knolls and ridges of drift which appear to be independent of drainage erosion and referable to the inequalities of deposition of the ice.

No paha have been found in Illinois except in western Whiteside and northwestern Henry counties in the districts in which some uncertainty is felt concerning the occupancy by ice at this stage of glaciation. The paha are scattered over the portion of Whiteside County north of Rock River from Round Grove westward to the borders of the Mississippi, but are best developed on the lowland tract south and east from Morrison and on the till tract between Rock and Green rivers, which leads from Spring Hill southwestward to the mouth of Green River. They are straight ridges, usually a mile or less in length, but occasionally reaching 2 miles. They are often sharp crested, with a width of scarcely 50 feet at top, and present abrupt slopes. Occasionally they reach a width of 40 or 50 rods, including slopes. In height they range from 10 feet or less up to about 50 feet. The trend is quite uniformly about WNW.–ESE. Several of them may be seen in the Clinton topographic sheet, Pl. XVIII (in pocket). The longest paha noted is found about 4 miles south of Morrison, and leads from the center of sec. 4 west-northwest to the north line of sec. 6, T. 20, R. 5 E., a distance of about

2 miles. It is interrupted by a narrow break in the west part of sec. 4, through which a small stream passes. This paha is 30 to 45 feet in height and 40 or 50 rods wide, including slopes. It presents the unusual feature of carrying basins on its slopes. One near the line of secs. 4 and 5 contains a pond with an area of about one-half acre. Another prominent ridge, apparently a paha, is found at Round Grove, that village being situated near its western end. The ridge is about 1½ miles long, 30 to 40 rods wide, and 20 to 40 feet high. It is separated by only a narrow sag, scarcely wider than the ridge, from an upland tract on the north which stands as high as its crest, and it may possibly be only a detached portion of that upland. It seems difficult, however, to account for a stream capable of causing its separation from the upland, and that interpretation would not be thought of if it stood like the paha last mentioned, some 3 miles from the upland. Just north of the village of Spring Hill there is a paha nearly a mile in length which rises about 20 feet above the general level of border districts and has a width of only 20 to 30 rods, including slopes. Several paha ridges appear on the low upland north of Green River in northwestern Henry County. The most prominent ones noted are a group of three nearly parallel ridges crossed by the Geneseo and Sharon wagon road 3 or 4 miles north of Geneseo, in sec. 34, T. 18, R. 3 E. Their highest points rise 40 to 45 feet above the bordering uplands, and they are each nearly a mile in length. Shorter ridges of about the same height occur in secs. 31 and 32 of the same township and in sec. 4, T. 17, R. 2 E.

There are in eastern Winnebago and Boone counties till ridges elongated in an ENE.–WSW. direction, apparently the direction of ice movement, which are drumlinoid in form. These ridges have been examined by Mr. I. M. Buell, in connection with his study of the drumlins of eastern Wisconsin, and he considers them a phase of drumlin development, though less perfect in form than the typical drumlin. These ridges usually have a length of a mile or less and a breadth scarcely half as great as their length. The higher ones rise 40 or 50 feet above border districts, but the majority are 30 feet or less in height. With these drumlinoid ridges there are associated knolls of nearly conical form, giving the surface a semi-morainic aspect. No definite morainic belts, however, have been traced across the district occupied by this ice sheet. The knolls appear in isolated clusters surrounded by plane-surfaced tracts of greater extent.

In the southeastern part of Winnebago County and in the portion of Ogle County between the outer moraine of the Wisconsin series and the present valley of Rock River, and also in southwestern Boone County, gravel knolls of considerable prominence are found. These in most cases appear to be a product of the Iowan invasion, for the gravel has a freshness corresponding to that of the Iowan till. In one instance (near King's Station, in Ogle County) a gravel knoll, opened for railway ballast, shows what appears to be a more aged gravelly deposit at the base than that constituting the body of the knoll. It had a height of 45 feet before the excavation was made, and several others in that vicinity are equally large, though the majority are 20 feet or less. A chain of sharp gravel knolls in southwestern Boone County, near Irene, trends north to south and has a length of over a mile. At the north it merges into a till ridge with gentle slope and with a smoother contour than the gravelly belt. This ridge, with the gravelly knolls, is probably a marginal deposit formed at a slight halt made by the ice. The knolls are only 20 to 30 feet high, but rise promptly from the bordering upland plain. Near Stillman Valley a few esker-like ridges of gravel are developed which trend northeast to southwest. These are closely associated with gravelly knolls, and the longest are only a mile or less in length. An esker-like ridge was also observed by Hershey near Sterling, Illinois.

The greater part of the surface of this sheet of drift, like that of the Illinoian sheet, is plane or but very gently undulating and devoid of notable topographic features. The principal ridges and knolls associated with the drift sheet are represented on Pl. XII, a reference to which will serve to show the small percentage of the area occupied by them.

THICKNESS OF THE DRIFT.

In eastern Winnebago and northern Boone counties, where the drumlinoid drift ridges and associated knolls abound, the drift of Iowan age is known to have considerable thickness, possibly an average of 40 feet or more. Aside from this small district, the drift referable to the Iowan invasion appears to form generally only a thin and somewhat patchy deposit. In the vicinity of the border the drift is often confined to the small knolls, 10 or 15 feet in height, the low ground among the knolls

being immediately underlain by an older sheet of drift. On hillside exposures also, some distance within the border, it has been found that in places a thin deposit of Iowan drift occurs at the tops of hills, while the greater part of the slope exposes Illinoian drift. In not a few places in the midst of the Iowan drift area only the Illinoian drift is found at the tops of the hills, though the hills were apparently covered by the Iowan ice sheet. There is apparently a smaller amount of loess associated with this ice lobe than with the Iowan of eastern Iowa. The districts immediately outside its border have only a thin coating, 5 or 10 feet, while the thickness of the loess within its borders is even smaller in amount. It would seem a liberal estimate to allow an average of 10 feet of both till and loess as the product of the Iowan invasion in Illinois. It is therefore sufficient to modify but little the features of the country which it occupies.

STRUCTURE OF THE DRIFT.

The drift of the Iowan invasion has generally a more sandy constitution than that of the Illinoian which underlies it. Along the wagon roads and in other situations where it has been exposed to the action of slight wash, it frequently presents the appearance of fine sand, where the Illinoian drift would present the appearance of clay. Not infrequently the matrix appears to be nearly free from clayey material. There are other places, however, where the till has a stiff clayey matrix, but is readily distinguishable from the Illinoian by its fresher surface. Associated as this till sheet is with the loess, the latter being apparently a derivation from the former, a sandy till is a natural product, the fine material being carried into the loess. This difference in the two tills greatly affects the character of the soils. Where the Iowan drift is present a dark soil is usually developed, while in the outlying districts of northwestern Illinois the soil is of a yellow or brown color.

In places the Iowan till is covered to a depth of several feet by loess, but in the Pecatonica Basin and much of the country east of Rock River the loess amounts to scarcely more than a skim coating 1 or 2 feet in depth, a coating such as may have been deposited by wind action since the final withdrawal of the ice sheet or have accompanied the melting of the ice. The portions best protected by loess present a till scarcely at all stained or

leached by atmospheric action, a feature which seems to indicate that the deposition of the loess closely followed the withdrawal of the ice.

Within the limits of the Pecatonica lobe there is a very sandy till liberally set with small fragments of limestone and usually leached to a depth of 2 to 4 feet. East from Rock River, in Winnebago and Boone counties, the till is, on the whole, less sandy than west of that stream. Several exposures were noted in railway cuttings between Roscoe and Caledonia in which the till becomes calcareous at a depth of but 1½ to 2 feet, but there is usually leaching to a depth of 3 feet or more.

Exposures of Iowan till were noted by the writer on the south and east borders of the city of Dixon. One on Second street and Dumont avenue shows a thin sandy capping, beneath which is fresh-looking calcareous till. Farther east the sand disappears, yet the till is found to have suffered leaching only to a depth of 3 or 4 feet and is markedly fresher than the Illinoian. In the south part of Dixon, along the Chicago and Northwestern Railway, the first cutting east of the crossing of the Illinois Central Railroad shows a calcareous sand, apparently Iowan, resting on a leached till in which no effervescence with acid could be obtained within 5 or 6 feet of top. In exposures farther east a thin capping of loess rests directly on the Illinoian till. There appears, therefore, to be only a patchy deposit of Iowan drift in the vicinity of this city. Hershey has noted several exposures of the Iowan between Dixon and Sterling, and west from there to Rock Island Junction. The common phase is a very sandy till, in places becoming clear sand.

In railway cuttings east from Polo low knolls belonging to the Iowan drift have been well exposed. They are capped by about 4 feet of loess-like silt, beneath which the till is found to be calcareous from top to bottom. It is more clayey than in exposures near Dixon and Sterling. In this locality the Iowan drift appears to be restricted mainly to the knolls, for exposures of the Illinoian drift appear in ditches made by the railway in crossing the low tracts among the knolls. At the village of Stratford, 5 miles east of Polo, the railway exposes a bed of fossiliferous silt at the base of the Iowan drift, resting on an old land surface formed on the Illinoian. The fossils appear to be entirely of one species (*Succinea avara*). In two other localities fossiliferous silts have been found at the base of the Iowan, one being in the railway cuttings on the Illinois Central immediately west of Irene, in southwestern Boone County, and another in the railway

cuttings on the Chicago and Northwestern, 1 mile east of Belvidere. Here, as at Stratford, the fossils are mainly of one species (*Succinea avara*).

The pebbles and smaller rock constituents of the till appear to be largely limestone whose native ledges are distant but a few miles to the east and north. In this respect it conforms to the structure of the underlying Illinoian sheet, and it seems not improbable that it has obtained much of the material from the Illinoian. There is not found between the Iowan and Illinoian till sheets of the Illinois lobe such a striking contrast in rock constituents as is reported by McGee and by Calvin to be found in the Iowan and Kansan of northeastern Iowa. The Iowan is reported by Calvin to carry scarcely any pebbles or large rock fragments of local derivation, while the underlying Kansan is thickly set with them.

The paha ridges of western Whiteside and northeastern Henry counties usually contain a peculiar phase of loess. The basal portion is a fine sand, rather than loess, in which many of the individual grains may be seen by the naked eye, though with some difficulty. The great majority of grains of ordinary loess are much too fine to be seen with the naked eye. From Round Grove the fine sand at the base of the paha ridge has been shipped to Chicago foundries for use as a molding sand.

In some cases the upper portion of the paha assumes a sandy constitution. As a rule, however, it consists of a loess similar to the bluff loess of the main waterways, and its banks will stand in vertical walls for years. Like the bluff loess, it is fossiliferous, but as yet, so far as the writer is aware, no determination of the species of fossils represented has been made. Before leaving this subject a few sections are presented from the debatable district in central and southern Whiteside County, which serve to show the freshness of the till and the occurrence of more than one drift sheet.

A well made for Mrs. Seeley on the slope of the Round Grove Ridge, at a level about 10 feet from the base, is reported by the driller to have penetrated the following beds:

Section of well of Mrs. Seeley at Round Grove, Illinois.

	Feet.
Earthy soil and subsoil	3
Fine yellow sand	5
Yellow clay, no pebbles noted	5
Soft blue pebbly clay (probably Iowan till)	8
Black dirt with wood embedded (probably Sangamon)	2
Till mainly of blue-gray color (probably Illinoian)	17
Limestone.	

The reference of the soft blue clay of this section to the Iowan is apparently supported by an exposure a short distance west of Round Grove, where the excavations at the side of the railway show a soft till which, though yellow at top, assumes a blue color within 3 or 4 feet of the surface. It has an appearance as fresh as any exposure of Iowan till noted in districts to the east. The exposure is not sufficiently deep, however, to show the depth of this till or to enable one to determine whether an older sheet underlies it. Directly east of Round Grove about 1½ miles, the loess is found to rest upon a till having leached and reddened surface, evidently as old as the Illinoian. These features indicate either that the Iowan ice failed to cover the district immediately east of Round Grove or that it did not form a continuous sheet of till. The first interpretation seemed to the writer at one time the more probable, but further reflection and consideration of the fact that this drift sheet is somewhat patchy in the districts to the northeast has led to a more favorable view of the second interpretation. If the fresh-looking drift found west of Round Grove is of Iowan age, the district to the east of that village was probably covered by that ice lobe.

West and south of Morrison, on the borders of Rock Creek and eastward from its valley, sandy till of fresher appearance than the Illinoian was noted at several points. In some cases it is found to be calcareous within 3 feet of the surface. At the point where the wagon road ascends from Rock River Valley toward Spring Hill an exposure was found in which the loess rests directly upon an unleached surface. It seems scarcely probable that there had been erosion of the till prior to the loess deposition, for the till surface there rises to its usual elevation in that locality. In the cases above noted also no evidence was found of any removal of the surface portion of the till. Exposures of till are rare in this region, partly because of the shallow depth of valleys and partly because of concealment by loess. The few above noted comprise all that were observed by the writer in central and southern Whiteside County.

STRIÆ.

A few exposures of striæ have been found in Winnebago and Ogle counties which fall within the limits of the Iowan drift sheet, but which are not referred positively to that ice invasion, since they may be referable to

the Illinoian. These have all been observed by Buell, who has kindly furnished a list of the localities and bearings for publication. They appear in the list on page 88.

PROBABLE EXTENT OF IOWAN DRIFT SHEET BENEATH THE WISCONSIN.

The extent of the Iowan drift beneath the Wisconsin can be determined only approximately, and chiefly by inferential reasoning. An inferential determination may be based upon the occurrence of a series of drift sheets sufficiently full to include the Iowan. For example, if there is but one older sheet of drift near the southern or western border of the Wisconsin, and if upon passing back beneath the Wisconsin two distinct sheets of older drift are found, it may be inferred that the additional sheet is either the Iowan or is a sheet still older than the Illinoian. A series of well sections have made it evident that there are three well-defined drift sheets in the northern portion of eastern Illinois, two of which are older than the Wisconsin. It may be difficult to determine whether the additional sheet is of Iowan or pre-Illinoian age, since the data are based almost entirely upon well sections, and the material thus obtained is scarcely adequate for a satisfactory determination. The complicated series extends as far south as southern Iroquois County, and may possibly extend into Vermilion and Champaign counties, though the sections obtained in those counties do not furnish such decisive evidence of the triple series as is found in Iroquois County.

The Wisconsin drift may usually be readily separated from the older sheets which underlie it. Its uniform blue color and the ease with which it may be penetrated by auger or spade enables the well drillers to distinguish it readily from the underlying deposits, which are of brown or gray color and more difficult to penetrate. There is also in many places a black soil at the junction of this sheet with the underlying drift which furnishes additional evidence of the passage from the Wisconsin to an older drift. The well records obtained in the flowing well district of southern Iroquois County have brought to light the occurrence of a second soil at a horizon 25 to 50 feet or more lower than the base of the Wisconsin drift. There is often considerable peat at this lower soil horizon, and with it a large amount of water-bearing sand from which the flowing wells are obtained.

The peat in one instance is found to have a thickness of 30 feet (in a well on Dr. Ludden's farm, 5 miles south of Clayton), and not infrequently has a thickness of 5 or 10 feet. Few wells have been sunk below this lower soil horizon, but these indicate that the drift may extend in places to a considerable depth. In several cases, however, the bottom of the drift was reached within 20 or 30 feet below the lower soil. Both sheets of drift beneath the Wisconsin are described to be of a brown or brownish-gray color, and the writer was unable to learn of any distinguishing characteristics. They are each described to be harder to penetrate than the overlying Wisconsin drift. In its surface exposures the Iowan is usually more easily penetrated by a spade or auger than the Illinoian, and this fact may seem to favor the view that the two sheets beneath the Wisconsin in Iroquois County are Illinoian and pre-Illinoian rather than Iowan and Illinoian. However, the information is so meager and the character of the observations so imperfect that it can scarcely be decided from these records whether the middle sheet is Iowan or Illinoian. The following data concerning the three sheets in Iroquois County will serve to set forth their relative thickness:

Clayton and vicinity.

	Feet.
Upper or Wisconsin drift sheet	60 or 70
Middle drift sheet	30 or 35
Lower drift sheet	45+

Ash Grove timber belt.

	Feet.
Upper or Wisconsin drift	55 or 60
Middle drift sheet	30 or 40
Lower drift sheet	50+

Crescent City and vicinity.

	Feet.
Upper or Wisconsin drift sheet	60
Middle drift sheet	15 or 20
Lower drift sheet	70+

Onarga and vicinity.

	Feet.
Upper or Wisconsin drift sheet	50 or 60
Middle drift sheet	30 or more
Lower drift sheet	175±

Gilman and vicinity.

	Feet.
Upper or Wisconsin drift sheet	75
Middle and lower drift sheets	120±

Milford and vicinity.

	Feet.
Upper or Wisconsin drift sheet	50±
Middle drift sheet	40 or 50
Lower drift sheet	25

Donovan and vicinity.

	Feet.
Upper or Wisconsin drift sheet	100±
Middle drift sheet	40
Lower drift sheet	30

In counties farther north a series is found similar to that displayed in Iroquois County. It is best shown in localities where the drift is very thick, as is the case in much of Kane, Dekalb, and McHenry counties. As these counties are adjacent to the exposed portion of the Iowan drift sheet and equally far to the north, there is scarcely a doubt that the middle sheet should be referred to the Iowan. Numerous sections of wells in these counties are presented in the portion of this report dealing with the wells of Illinois (Chapter XIV), together with a discussion of the probable age of the sheets, where more than one was penetrated. From these it may be seen that the Middle or Iowan drift, as in the exposed portion, is much thinner than the Wisconsin and has a depth about the same as the middle sheet in Iroquois County. These points of resemblance, although not demonstrative of contemporaneity, at least suggest the possibility that the Iowan drift extends into Iroquois County.

A loess-like silt, as shown below, covers the Illinoian drift of southern Illinois outside the limits of the Wisconsin and is traceable northward several miles beneath the Wisconsin. This appears to be a deposit of Iowan age like the loess of western Illinois, and, like the loess, it may be derived from the ice sheet. Its presence in southeastern Illinois and also in districts farther east, for it is found as far east as central Ohio, is thought to bring strong support to the view that the ice sheet, at the Iowan stage, did not fall short many miles of reaching the line occupied at a later date by the Wisconsin ice invasion. This silty outwash is of sufficient volume to mantle the region, as far south as the Ohio River, with a deposit having an average depth of probably 5 feet. The volume of this deposit would seem to indicate that the southern limits of the ice sheet from which it was derived were at least within 100 miles, and possibly much nearer, the southern limits of the Wisconsin drift sheet, not only in Illinois, but in Indiana and Ohio.

PROBABLE EXTENT OF THE IOWA PORTION OF IOWAN DRIFT.

Inasmuch as there is some evidence suggesting a slight extension of ice from Iowa into northwestern Illinois at the Iowan stage, the question of the extent of that ice sheet is here considered.

The "upper till" of northeastern Iowa now classed largely as Iowan drift is represented by McGee to have its eastern border near the western edge of the Driftless Area from the Minnesota-Iowa State line southeastward to the southern point of the Driftless Area near Sabula, Iowa.[1] Generally it falls short a few miles of reaching the Driftless Area, but in southern Jackson and in Clinton County, Iowa, it is represented to extend beyond the earlier sheet and to constitute the border of the Driftless Area. It is represented to extend to the Mississippi Valley from northern Clinton County southward to Scott County, and to fall short but a few miles of reaching that valley in Scott and Muscatine counties. A tectonic map[2] represents the ice sheet to have extended across the Mississippi and rested on the east bluff for a few miles below Clinton. From Muscatine County westward the limits are not definitely given. The upper till, however, is represented to extend to the limits of the district reported upon.

The investigations carried on by the Iowa survey have supported the mapping and results of McGee in a general way, but not in all details. Very little disagreement as to the boundary is found from the Minnesota-Iowa State line southward to Delaware County, Iowa. But from that county southward to eastern Jones County Professor Calvin, of the Iowa survey, places the limit of Iowan drift a few miles inside McGee's limit. There are certain extramarginal phenomena recognized in the disputed territory which he considers closely related to the Iowan invasion, but not requiring the presence of Iowan ice, chief among which are heavy accumulations of loess and a tendency to ridging of the loess in lines trending from WNW. to ESE., as in the undoubted Iowan area.

From northern Jones County eastward to the Mississippi the border has not yet been investigated by the Iowa survey, but the writer made some examinations in this district in 1894 while engaged in tracing the west border of the Illinoian drift. The examinations were begun in Clinton County and carried westward. On the uplands northwest of Clinton a belt

[1] Eleventh Ann. Rept., U. S. Geol. Survey, Pl. XLIV. [2] Op. cit., Pl. LVI.

of thick drift was discovered along which rock is seldom encountered at less than 80 feet, and in places the drift reaches a thickness of 200 feet or more. This thick belt of drift has a breadth of 3 or 4 miles and at first was conjectured to be the marginal ridge of the Illinoian drift, though it is somewhat broader than the general width of that ridge in southeastern Iowa. It carries a thick capping of loess (20 to 30 feet or more) which greatly obscures the glacial deposits. A few exposures were found, however, which showed a surface reddening and leaching of the till such as is displayed in the Illinoian or Kansan sheets of drift. Such reddening has not been found in loess-covered portions of the Iowan drift in northwestern Illinois, nor, so far as the writer is aware, has it been noted in the Iowan drift of northeastern Iowa. These observations were made in the district where only the upper till is represented on McGee's map. The writer, therefore, inferred that the upper till here should be considered Illinoian and proceeded westward, expecting to find the belt of thick drift swing southward to connect with the margin of the Illinoian already traced to western Scott County. It was found that the "Goose Lake Channel," described by McGee as an old course of the Mississippi, cuts through this belt immediately south of the village of Goose Lake (see Pl. XVIII). From the west side of this broad valley the belt continues nearly due west across northern Washington and Welton townships, occupying its usual width of 3 or 4 miles and constituting the divide between the Maquoketa and Wapsipinicon rivers. It there takes a course north of west, passing between Elwood and Lost Nation and still constituting the water parting between the two drainage systems. Slight incursions into the district north of this belt showed only thin deposits of drift resting on or mingled with residuary clays. The thick drift was traced to the vicinity of Onslow in Jones County, and there the examination was discontinued, for it had become evident that this belt of drift could not connect with the Illinoian margin in Scott County. In returning eastward it was found that the thick drift, with its heavy coating of loess, lies along the north edge of a plain of Iowan till, strewn with the immense bowlders characteristic of that deposit and presenting only thin or patchy developments of the loess.

At Dewitt Prof. J. A. Udden joined the writer for a couple of days' study, and a trip was made together from Dewitt to Sabula. The large

Iowan bowlders were found east as well as west of Goose Lake Channel, as far north as the south edge of the belt of thick drift, but were not observed farther north. The first night was spent at Bryant, near the north edge of the belt of thick drift, and in the vicinity of this village a few exposures of the drift were found at the base of the loess, all of which showed a leached and reddened surface. Continuing northward from Bryant to Miles the loess was found to remain nearly as heavy as on the belt of thick drift, but the glacial deposits were very much thinner and seemed to be restricted to small bowlders and pebbles of crystalline pre-Cambrian rocks. These were usually found embedded in a slightly disturbed residuary clay of a deep reddish-brown color which can scarcely be called till, the commingling of pebbles with residuary material being so imperfect. Between Miles and Sterling the surface is ridged in a peculiar manner, though somewhat similar to the paha of the neighboring county on the west (Jones County) in trend and form, the trend being WNW. to ESE. and the form somewhat similar to an inverted canoe. The wells made on these ridges were reported to have penetrated "clay and quicksand," and in some cases have reached a depth of 40 feet without entering solid rock. As no exposures were found, the precise nature of the deposits remain undetermined. A few granitic and greenstone pebbles were found in ravines between Sterling and Sabula, showing that the glacial deposits occur a few miles outside the limit mapped by McGee.

Reviewing the above observations, it appears that nothing to suggest the occurrence of Iowan drift was found along or north of the belt of thickened drift except the paha-like ridges near Miles, and there the resemblance is not known to carry with it the interpretation that they are of similar origin or date to the paha of the clearly recognized Iowan drift. At best the paha are still an enigma from which as yet nothing can be proved. In view of the very thin and somewhat patchy development of the Iowan drift near the terminus of the lobe in Ogle and Lee counties, Illinois, some hesitancy is felt in declaring the Iowan drift to be absent from northern Clinton and southern Jackson counties, Iowa. For in the latter counties the heavy deposits of loess greatly interfere with the determination of its extent. The occurrence of a sheet of drift markedly older than the Iowan in the district mapped by McGee as occupied only by upper till is abundantly evident. The thickened belt of this older drift merits further

investigation, especially since in some of its features it suggests a terminal moraine.

During the past season (1897) the writer, together with Mr. Oscar Hershey, made further observations in eastern Clinton County, Iowa, as well as in Henry, Whiteside, and Carroll counties, Illinois. At Clinton the glacial deposits on the bluff of the Mississippi are found to be very thin, amounting usually to but 5 or 10 feet. These deposits, however, appear to be capable of separation into two distinct till sheets. One is reddened and leached at the junction with the overlying loess and apparently is much older, while the other is scarcely at all leached or stained at the junction with the loess and in one locality appears to graduate upward into loess. The former deposit is probably of Kansan age while the latter appears to be Iowan. The best exposure noted is found a short distance northwest of the Clinton Brewery in sec. 1, Clinton Township. The loess here has a thickness of 20 to 25 feet. At its base, near the east end of the exposure, is a fresh-looking calcareous till, about 4 feet thick, resting upon a bed of rotten, deeply stained gravel which there caps the older till. A few rods west the older till comes up to the base of the loess and farther west there are several exposures in which the loess rests directly upon the older till. Had the exposure of fresh till not been observed, there would have been nothing to indicate the presence of an Iowan drift at this locality. Such being the case here, where exposures are extensive, it can scarcely be affirmed that the Iowan drift is not present in the district immediately north and west, where only slight exposures can be found beneath the heavy covering of loess. The exposure just mentioned was visited in November, 1897, by Messrs. Calvin, Udden, Bain, and the writer, and the interpretation given above was assented to without reserve. Hershey and the writer noted two exposures in the bluff in the north part of North Clinton (formerly Lyons) in which a few feet of fresh-looking till rests directly upon the residuary clay of the underlying limestone, a till which seems referable to the Iowan rather than Kansan. Southwest of Clinton along the Burlington, Cedar Rapids and Northern Railroad bowlders were noted by Messrs. Calvin, Udden, Bain, and the writer near the east bank of the Mississippi. They are of the large angular type recognized by Calvin as characteristic of the Iowan, and they occur on a gently undulatory plain, such as is also characteristic of the Iowan. Similar bowlders were observed by the same

party of geologists near Long Grove in northern Scott County, and are reported to occur for several miles farther east. Here also they occur on a plain referred with some confidence to the Iowan stage of glaciation. Having traced undoubted Iowan deposits to the border of the Mississippi, it becomes a matter of interest to determine whether the Iowan ice crossed into Illinois.

The examination made by Mr. Hershey and the writer in Whiteside and Carroll counties, directly east from the district just discussed, brought to light several features of a puzzling nature, some of which may have direct bearing upon this question. These features fall into five classes, (1) fresh till; (2) a tract free from loess; (3) a sand border east of the fresh till; (4) a loess apron outside the sand border; (5) ridges of loess with similar trend to the paha of the Iowan drift area. Certain other features found in southern Whiteside and northwestern Henry counties are considered in connection with the probable extension of the Illinois lobe at the Iowan stage. The features here considered lie outside the probable limits of that lobe.

Deposits of fresh-looking till occur on the elevated upland about 10 miles due east of the north part of Clinton, near the south line of sec. 13, Ustick Township, and near the west end of the line of secs. 18 and 19, Clyde Township, Whiteside County. The till has a yellowish-gray color similar to that of the Iowan near Polo, in Ogle County, and effervesces at a depth of less than 2 feet from the surface of the ground. As the exposures occur in the midst of a tract nearly free from loess, there is nothing to protect the till from leaching. It is in marked contrast to numerous other till exposures in the immediate neighborhood, which show decidedly stronger surface stain and are leached to a depth of 5 or 6 feet. These exposures of fresh-looking till were visited by Calvin, Udden, Bain, and the writer in November, 1897, and by all were recognized to present a much fresher appearance than the surrounding exposures. It was also recognized that advantages for erosion here seem no greater than at points where a stained and deeply leached surface is presented. Although several different lines have been traversed by Hershey and the writer in Carroll and western Whiteside counties, no other exposures of such fresh till have been noted outside of the possible limits of the Iowan sheet formed by the Illinois lobe. These exposures, it will be observed, occur within the limits of a single square mile. Taken by themselves they seem a weak, though perhaps not

uncertain, prop to support the hypothesis of an extension of ice from Iowa into Illinois at the Iowan stage of glaciation.

The elevated tract just noted stands near the south end of a strip which is nearly free from loess. The strip extends northward several miles into Carroll County and has a general width of only about 2 miles. It is in decided contrast with the thick belt of loess on the west which follows the east bluff of the Mississippi and probably averages not less than 30 feet in average depth. It is also in contrast with the district on the east which for a distance of several miles back is covered to a depth of 12 to 15 feet with loess. On the south also there is heavy loess separating this tract from a similar tract south and east of Morrison. The tract with scanty loess is in an exposed situation, but apparently no more so than the bluff of the Mississippi both to the west and south. It, therefore, seems difficult to account for its scant deposition by the force of the wind. It stands like the fresh till as a feature out of harmony with the general features of the region. It seems, however, to have a parallel in the region of Iowan drift to the west, where similar areas free from loess are bordered by loess-covered tracts. In this connection it may be remarked that the belt of loess along the Mississippi bluff leads down the river from far to the north and may be somewhat later than the loess to the east, and possibly subsequent to the occupancy of eastern Iowa by the Iowan ice sheet.

East of this tract characterized by thin loess is a narrow sandy belt in which dunes are common. This belt is best developed in Clyde Township, Whiteside County, where it has a breadth of fully 1 mile. Its southern end is found at Rock Creek Valley about 5 miles above Morrison, as indicated on Pl. XII. From this point it bears slightly west of north into Carroll County, lying mainly east of the valley of Little Creek. Its general altitude is slightly lower than the tract on the west, but it has about the average elevation of the region, being not less than 200 to 250 feet above the Mississippi River. It is so far removed from the river as to be outside the range of the æolian deposits which in places accumulate on the east bluff. The best developed portion, as may be seen by reference to Pl. XII, stands 6 to 10 miles back from the river bluff and is separated from it by the still more elevated tract just discussed.

On the south, east, and north borders of the sandy belt there is a blanket of loess 12 to 15 feet thick near the margin of the sand, but decreasing

in thickness to scarcely half that depth within a few miles east or north, beyond which for many miles it continues thin. The distribution and general relations of this loess in reference to the district west of it present some points of similarity to the loess borders of the Iowan drift in northeastern Iowa where the loess is considered an outwash or overwash apron from the ice sheet, formed while it occupied the neighboring tracts of Iowan drift, which are nearly free from loess. The thinning out of the loess upon passing a few miles back from the hypothetical ice margin, as well as the abrupt border next the ice margin, may here find illustration just as in Johnson County, Iowa.[1]

The remaining feature bearing upon the question of the Iowa invasion into northwestern Illinois is that of canoe-shaped ridges of loess, with parallel shallow troughs, having a WNW.–ESE. trend. Such ridges and troughs are best developed in a belt of thick loess lying between the strip of thin drift just considered and the valley of Rock Creek in western Whiteside County (see Pl. XVIII). There are other well-defined ridges, as already noted, south and east of Morrison, in the lowland tract nearly destitute of loess, and a few have been found south of Rock River in northwestern Henry County. There is a faint development of this class of ridging in northern Rock Island County, Illinois, and in southern Scott and eastern Muscatine counties, Iowa. It is, perhaps, significant that they are best developed in the district lying between the well-defined phases of the Iowan drift of the two ice lobes. While the origin of this class of ridges like that of the loess sheet is in all probability attributable to a combination of aqueous and æolian agencies the precise mode of action and relation of the two agencies have as yet received no adequate explanation. These ridges and bordering troughs were apparently developed before the present drainage lines had been opened in that region, if not while the ice occupied the neighboring drift plains on which the loess is a scanty deposit. The length of the ridges ranges from a fraction of a mile to two or three miles, but the width seldom reaches one-eighth of a mile. In height they range from 5 feet or less up to about 50 feet. While usually made up of typical loess they occasionally include fine sand, as noted above (p. 139.)

Aside from the canoe-shaped ridges of loess there are found other forms of loess and sand aggregation in the region under discussion. On the east

[1] See Calvin, Iowa Geol. Survey, Vol. VII, 1897, pp. 86–90; also map of Johnson County, p. 92.

bluff of the Mississippi Valley, opposite the broad sandy bottoms, such as occur in southwestern Carroll and northwestern Whiteside counties, sandy knolls and ridges are found which are evidently due to wind action. Some of them are in process of drifting even to-day, for the sand is too barren to nourish an adequate protective cover of vegetation. These ridges are irregular in form and trend and seldom bear a resemblance to the canoe-shaped ridges of loess. A few sandy ridges are found on the strip of drift in southwestern Carroll County, above noted, where the loess is scanty, which like the canoe-shaped ridges of loess have a general WNW.–ESE. trend. They are, however, more irregular in form and are usually broader than the loess ridges. Possibly they should be classed with the dunes.

If all the features of the region just discussed be considered, it appears that positive evidence of the invasion of the Iowa ice into northwestern Illinois at the Iowan stage of glaciation is at best very weak. The features, however, appear to favor rather than to antagonize the hypothesis of such an invasion. The debatable ground is restricted to a belt but 10 or 15 miles wide on the north and east borders of unquestioned Iowan drift. It embraces northern Clinton and southern Jackson counties, Iowa, and southwestern Carroll, western Whiteside, and possibly neighboring portions of Rock Island County, Illinois. Were this belt low, like the tracts occupied by the Iowan drift in Clinton and Scott counties, Iowa, the extension might be granted, even with a very limited occurrence of fresh-looking drift. But the fact that the debatable region, both on the north and east, stands 100 to 300 feet above the low plain of Iowan drift, necessitates a very careful study of the evidence in the light of all applicable hypotheses. Having set forth the available data, the question is left open with the hope that either by the light of further data or by more mature reflection a satisfactory solution may be reached.

RELATION OF THE ILLINOIS AND IOWA ICE LOBES.

In concluding this discussion a few remarks seem necessary concerning the probable relation of the Illinois and Iowa ice lobes at the Iowan stage of glaciation. In his paper on northeastern Iowa, above quoted, McGee considers it probable that at the invasion now called Iowan the ice from the Iowa side culminated earlier than that on the Illinois side, and caused a displacement of the drainage of the Mississippi near Clinton, southeastward

to Rock River.[1] He has represented the Illinois lobe to have subsequently extended to the border of the Mississippi Valley in Whiteside and Rock Island counties, and to have led to the flooding of the Driftless Area, forming what is termed Lake Hennepin.[2] It would appear from McGee's discussion that the dates of culmination of the two lobes were separated by only a brief interval, an interval which in no wise compares in length with that which has been found to have occurred between the Kansan invasion of the Iowa lobe and the Illinoian invasion of the Illinois lobe, and that one lobe held nearly its maximum extent until the other culminated. The relations of the two lobes of the Iowan invasion appears to have been largely a matter of conjecture, for it is now found that the Illinois lobe fell far short of reaching the limits assigned to it by McGee. It is doubtful if evidence has yet been collected by which it will be possible to demonstrate clearly either the space or the time relations of the two ice lobes.

The space relations as well as time relations of the two lobes being still unsettled, the influence upon drainage is at best a matter of conjecture. The Iowa ice lobe appears to have reached as far east as the Mississippi River in southern Clinton and northern Scott counties. Possibly it reached a few miles beyond the river in southwestern Carroll, western Whiteside, and northern Rock Island counties, Illinois, though such an extension is, as already noted, but weakly supported. The Illinois ice lobe certainly extended a few miles beyond Sterling on the north border of Rock River Valley and probably extended about to Geneseo, on the south border of that valley. The debatable tract east and south of Morrison, in central and southern Whiteside County, was apparently covered at the Iowan stage, either by the Illinois or by the Iowa ice lobe. If the latter is found not to have extended beyond the Mississippi Valley, it would follow that this district was occupied by the Illinois lobe.

The question of a coalescence of the two lobes, or the overlapping of their fields, depends, therefore, upon the determination of the extent of the Iowa lobe. If that lobe did not extend beyond the Mississippi, there would remain a strip about 8 miles in width along the east border of the Mississippi Valley which remained uncovered by ice throughout the Iowan invasion. By including the valley its width would be increased to 10 or

[1] Eleventh Ann. Rept., U. S. Geol. Survey, p. 570.
[2] Op. cit., Pl. LVIII; also pp. 570-577.

12 miles; it would embrace the belt of heavy loess west of Rock Creek, in Whiteside County, at the points where the lobes made their closest approach. A belt of this width would, when taken in connection with the valley of the Mississippi River, apparently have afforded an adequate line of discharge for the streams of the Driftless Area, and also for the waters issuing from the melting ice lobes. If, on the other hand, the Iowa lobe extended to the vicinity of Round Grove and Spring Hill, Illinois (see Pl. XII), and reached this culmination at the same time that the Illinois lobe had its maximum extension, there may have been a coalescence of ice for a breadth of perhaps 15 or 20 miles. This appears to represent the extreme possibility of coalescence. Granting such coalescence, it remains questionable whether a glacial lake could have been held in the region north of the junction of the lobes. The existence of Lake Hennepin appears, therefore, to rest upon exceedingly weak foundations so far as the influence of coalescing ice lobes is concerned. It is doubtful if a body of water of greater depth was present in the district north of these lobes than in the district south of them. It is generally supposed that the loess was deposited under conditions of very imperfect drainage, and that the districts which it covers were, in large part, under water for at least brief intervals. The extent and duration of the flooding, both to the north and south of the districts occupied by these ice lobes, is still largely a matter of conjecture, and a subject on which wide differences of opinion exist. With these remarks we pass to the discussion of the Iowan loess.

THE IOWAN LOESS.

DISTRIBUTION.

Deposits of silt, tentatively classified with the loess and supposed to be of Iowan age, cover the entire surface of the Illinoian drift so far as it lies outside the limits of the Iowan and Wisconsin drift sheets, not only in Illinois, but also in Iowa and in States to the east as far as Ohio. These deposits have been extensively removed by stream erosion on a considerable part of the slopes and in the valley bottoms, but still remain nearly intact on the uplands. They have been traced back several miles beneath the edge of the Wisconsin drift in central and eastern Illinois, but the full extent has not been ascertained. A portion of the Driftless Area in Illinois,

both in the northwest corner and in the southern end of the State, were almost entirely covered by loess, though possibly some of the highest knobs and ridges escaped.

In northern Illinois, where the Iowan drift sheet is exposed to view outside the limits of the Wisconsin, the loess-like silts are irregularly distributed. The Pecatonica lobe and the districts to the east, in Winnebago, Boone, western McHenry, and northern Dekalb counties, have scarcely any typical loess, and the silt deposits seldom exceed a depth of 1 or 2 feet. It is not certain that these deposits are of similar origin and date to the silt deposits on the west border of the Iowan drift. In passing southward from the Pecatonica lobe loess-like silts overlap the Iowan drift to a distance of several miles. In northern Lee County Illinois, they extend some miles east of Rock River. Upon approaching the Green River Basin sandy deposits appear which effectually conceal any silts which may have been deposited farther south. However, the belt of drift thought to be of Iowan age that is situated on the south border of the Green River Basin is not sand covered. This has a much thinner deposit of silt than the Illinoian sheet to the south, and much of its surface seems never to have been coated with silt.

Attention has been called to the existence of a tract nearly free from loess in southwestern Carroll and northwestern Whiteside counties, Illinois, which may find its explanation in ice occupancy of the territory up to a date so late that the loess was barred out. There are quite extensive loess-covered tracts within this area, notably one which follows the Mississippi Valley. This belt of loess seems to be a continuation of the extensive belt which follows the west side of the Driftless Area throughout almost its entire length, and is perhaps somewhat later than the loess deposits made on uplands below the Driftless Area. Aside from this main belt along the Mississippi River there is a heavy loess deposit in northern Whiteside County, which is probably as old as the loess on the districts to the east. Loess is also found on much of the narrow uplands lying between Rock and Green rivers from Spring Hill southwestward to the junction of these streams. In addition to the loess which is deposited in sheets there is in this region a loess capping the paha ridges. In some cases the paha are coated to a depth of 15 feet or more, while bordering plain tracts are nearly free from loess. In other cases the loess appears to be nearly as heavy on the plain tracts as on the paha. The distribution in the Iowan area is so irregular and patchy

that very detailed study is necessary to determine its limits. The general extent of the loess and associated silts may be seen by reference to the glacial map (Pl. VI).

VARIATIONS IN THICKNESS.

The variations in thickness of the loess apparently depend largely upon the relation (1) to the ice margin and (2) to the principal lines of drainage. On the margin of the Iowan ice sheets, especially the one which occupied eastern Iowa, there is a thicker deposit of loess than in districts remote from the ice margin. Also in Carroll and Whiteside counties, Illinois, there is a belt of loess extending from the hypothetical margin of the Iowan ice sheet above outlined northward to the south border of the Pecatonica Basin and eastward to Elkhorn Creek, in which the loess has a thickness of 15 to 20 feet, while in the districts immediately north and east its average thickness does not much exceed 5 feet. The features here as well as elsewhere seem to indicate that the outwash from the Iowan ice was much heavier within 10 or 15 miles from its border than at greater distances. The ice lobe which extended southwestward into northern Illinois has a less marked thickening of the loess near its border, though Mr. Hershey reports a perceptible thickening on the borders of the Pecatonica lobe. On the south border of the Green River Basin there is, however, a marked thickening of the loess at the line supposed to mark the southern limits of the Iowan ice sheet. The thickness is nowhere much less than 25 feet and in places is fully 40 feet. Upon passing southward the thickness soon decreases to 12 or 15 feet, and about this thickness is maintained over much of the area between the Illinois and Mississippi rivers.

The thickening of the loess along the borders of the main drainage lines is well illustrated by the Mississippi. On the borders of this valley in northern Illinois there is 25 to 40 feet of loess, but within 5 or 10 miles east of the bluff the thickness usually decreases to less than 10 feet. Following down the Mississippi, there is found to be a heavy deposit of loess on its immediate borders, passing through the area which was occupied or closely bordered by the Iowan, as well as in districts to the north and south, a feature which seems to indicate that the loess deposition occurred after the withdrawal of the ice lobe to the west side of the river. Upon passing into the district south of the limits of the Iowan ice lobe the loess

decreases in thickness, especially on the Iowa side of the river. From a thickness of 40 feet at Muscatine it decreases to but 10 or 12 feet at Burlington and to about 6 feet at Fort Madison. On the east side of the river, however, the loess maintains a thickness somewhat greater than on the west, there being immediately opposite Fort Madison twice as thick a deposit as on the Iowa side. This extra thickness is perhaps attributable to wind, for along the eastern bluff of the river there are dunes composed of fine sand drifted by the wind from the broad bottoms. The prevailing wind being from the southwest, the dunes are found only on this bluff.

The Illinois Valley is bordered both on the east and west below the mouth of the Sangamon River by heavy accumulations of loess, 40 to 50 feet or more. But upon passing back a distance of 5 or 10 miles from the stream, on either side, the thickness becomes reduced to 8 or 10 feet. The heavy loess of the Illinois and Mississippi valleys, together with a belt along the Missouri valley, continues down the Mississippi to the Gulf of Mexico. On the borders of southern Illinois the thick loess is confined to a belt but 5 or 10 miles in width, the thickness farther east being scarcely one-fourth as great as on the immediate borders of the stream. In central and southern Illinois the thickness of the loess seldom exceeds 10 feet and probably averages not more than 6 feet. The Kaskaskia, Embarras, and other streams of south-central and southern Illinois do not have such heavy belts of loess on their borders as characterize the Illinois, Mississippi, and Missouri valleys. There is but little thickening upon approaching the Wabash River, the average thickness along the west bluff of the stream being less than 10 feet.

On the lower portion of the Ohio from near Rockport, Indiana, to its mouth, loess deposits are 15 to 25 feet in thickness, but above Rockport the thickness is seldom more than 5 or 6 feet, and this thickness prevails over southeastern Indiana and southern Ohio.

STRUCTURE.

The loess and associated silts are not so uniform in structure as might be inferred from some of the published descriptions. The earlier descriptions apply to a very porous deposit found on the borders of the large valleys which was the first to attract the notice of geologists and which may be designated bluff loess. The great extent of the surface silt over

the plains between the streams has been known for only a few years. In the region under discussion the first recognition of the interfluvial silts as a deposit distinct from the glacial drift appears to have been made by Professor Salisbury in his studies on the borders of the Driftless Area in 1885 and in southern Illinois at a later date. The discussion of loess in the Illinois geological reports apply chiefly to the deposits on the immediate borders of the main valleys, though some recognition of its extent into the region about Springfield appears to have been made by Professor Worthen and his associates.

The structure of the loess varies in vertical sections as well as from place to place. The leading variations in the vertical sections are such as to support a threefold division: (1) The surface portion, 2 to 4 feet in depth, which has an earthy structure due probably in part to the breaking down of many of the grains under atmospheric action. This phase characterizes not only the deposits on interfluvial tracts, but also those on the borders of the main valleys, as is natural if the earthy appearance is due to atmospheric action. (2) The main body of the loess, which is a silt usually without definite bedding planes or stratification. It is somewhat more porous on the borders of the main valleys than beneath the interfluvial tracts. The variation in texture is apparently due to the removal of the finer material on the borders of the valleys rather than to the presence of coarser material there than in the interfluvial tracts. (3) The basal portion, which commonly shows a more distinct bedding than the body of the loess, and is in places sandy and pebbly. As a rule the pebbles are confined to the lower 2 or 3 feet, but in the thicker portions of the loess the well-defined bedding may occupy a depth of several feet. The pebbles often occur in places where the bedding is not distinct. Indeed, the most distinctly bedded portions are usually almost free from pebbles.

In following the loess from place to place across the interfluvial tracts it is found to undergo gradual changes in texture and color, for which a cause is not in all cases manifest. But as a rule the more porous portions of the loess are found in proximity to a large valley or to the border of the Iowan drift sheet. Upon passing back from the valleys the open texture becomes less pronounced, and there is a gradual change to a clayey loam and then to loamy clay. A similar change in texture is found in passing away from the border of the Iowan drift sheet. This is well shown both in

southeastern Iowa and western Illinois. In the vicinity of Iowa City, along the borders of the Iowan drift sheet, the loess is so porous that water readily penetrates it and tile draining is seldom necessary. But upon passing southward across Washington, Louisa, Henry, and Des Moines counties, the texture becomes gradually finer, and extensive areas in the southern part of the State require tile draining. In northeastern Missouri the texture is still more compact, so that a large portion of the rainfall is disposed of by surface evaporation. Similarly in western Illinois the loess of Henry, Rock Island, and Mercer counties is more porous than that of counties immediately south. But in this region the belt of porous loess along the Mississippi and that along the Illinois occupy so much of the interval between the streams that there remains only a narrow strip of compact loess in the vicinity of the divide. East from the Illinois River, as far as the divide between this stream and the Kaskaskia, the loess is sufficiently porous to require but little tile draining. The Kaskaskia drainage basin and much of southern Illinois, like northern Missouri, has a surface silt too compact to absorb the rainfall. The loess in this region has become so puddled (perhaps because of the process of soaking and drying to which it has been subjected) that underdrainage is difficult. Throughout much of the region a hard ferruginous crust immediately underlies the soil at a depth of 12 to 15 inches or less, which needs to be broken before underdrainage can be established. The compact silts of southern Illinois present an ashy appearance near the surface, which gives them the name of "white clay." It is rare to find even an inch of black soil on their surface. In this respect they are in striking contrast to the silts west of the Kaskaskia Basin, in which a black soil several inches in depth is generally present. The white clay district is continued eastward into Indiana and southwestern Ohio, occupying much of the interval between the glacial boundary and the southern edge of the Wisconsin drift sheet.

The mineralogical constitution of the loess and determinations of the size of its grains has been given considerable attention by Salisbury, and the results are presented in the Sixth Annual Report of this Survey. The samples selected were chiefly from localities adjacent to the Driftless Area on each side of the Mississippi. It was found that of 150,887 particles measured, 146,894, or about 97¼ per cent, are less than 0.005 millimeter in diameter, leaving only 2¾ per cent of greater size. The largest particles

noted were of a flattened form, many of them being mica scales. The extreme size noted was 0.1139 by 0.0285 millimeter. A prominent characteristic of the loess grains is their angularity and their irregularity. "Sharp corners and rough surfaces are the rule and any approach to regularity or smoothness the exception." The mineralogical examination shows that quartz greatly preponderates, while particles of feldspar, mica, hornblende, augite, magnetite, dolomite, and calcite are present, the mineral constitution being not greatly different from that of the glacial deposits from which the loess is probably largely derived. It is found that loess in the Driftless Area has been modified by the introduction of residuary material, and is therefore formed in part of true loess material and in part of wash from the residuary soil of the surrounding country.[1]

Samples of the several grades of loess were collected in 1892 by the writer in various parts of western, central, and southern Illinois and sent to Prof. Milton Whitney, of the United States Department of Agriculture, for mechanical analysis. Several samples were analyzed under Professor Whitney's direction by Prof. J. A. Udden. The separations were made substantially after Johnson and Osborn's "beaker method." The results have been published by Whitney in a report to the Illinois Board of World's Fair Commissioners.[2] The following tables, taken from Whitney's report, are rearranged to bring out the distinction between loess supposed to have been wind deposited and that which may have been deposited by water. Other changes in the grouping of the analyses have also been made. The analyses of bowlder clays are introduced, in order that their physical constitution may be compared with that of the loess and white clay. It will be observed that in the bowlder clay the percentage of fine material (0.005 millimeter or less) is greater than in typical loess, thus suggesting the partial removal of such material from the loess. The tables bring out clearly the fact that the pervious loess contains a smaller percentage of fine particles than the compact, but that it contains no coarse particles. They also show that in the pervious loess the soil contains a larger percentage of fine particles than the subsoil. Whitney remarks that the loess soil and subsoil show the reverse of the rule in agricultural lands, it being the rule that the subsoil

[1] Sixth Ann. Rept. U. S. Geol. Survey, pp. 278-285.

[2] Report on the examination of some soils from Illinois, by Milton Whitney. Final Report of Illinois Board of World's Fair Commissioners, 1893, pp. 93-114. Published at Springfield, Illinois, in 1895. H. W. Rokker Printing Company.

contains a greater percentage of fine particles than the soil. An interesting contrast between loess and residuary earths is thus indicated. As noted above, the surface portion of the loess probably owes its finer constitution in part to atmospheric action, through a breaking up of the particles. It is probable also that dust transported by the wind, and very fine material, such as is constantly floating in the atmosphere, tend to increase the percentage of fine material at the surface. There may also have been an original difference in the coarseness, for there is generally found to be an increase in porosity toward the base of the loess.

In the table of wind-deposited soils two analyses of fine sand are included, one sample obtained at Mason City on the east border of a sand-covered basin along the Illinois, the other from a belt of sand which fringes the Sangamon River bluffs in northern Christian County. The entire absence of coarse sand in these deposits distinguishes them from water-bedded sand on the terraces of neighboring streams. Analysis No. 1338, from an Illinois River terrace where stream action was operative, shows nearly 5 per cent of coarse sand.

The final table presents analyses of a variety of soils. Two of these (the gumbo from Mississippi bottoms near East St. Louis and the soil from the old lake bottom near Chicago) contain a greater percentage of clay than is found either in the compact loess or the bowldery clay. All other analyses of water-deposited silts and sands from Illinois indicate a partial removal of the clay or fine material, but in these samples there appears to have been an accession or concentration of this material. The sample from Rockford represents a thin deposit of silt capping the Iowan till sheet. It contains coarser particles than are found in the loess outside the border of the Iowan drift.

In comparing the measurements given in these tables with those made by Salisbury it should be borne in mind that Salisbury's measurements refer to number of grains, while Whitney's refer to the bulk of the material. The percentage in number of grains in Whitney's tables may be readily estimated from the data presented in the column showing the number of grains per gram. Thus at Virginia City the subsoil analysis (No. 1318) shows about 96 per cent, and that at Dubuque (No. 1347) shows 97.7 per cent below 0.005 millimeter in diameter. As the average of Salisbury's analyses show that about 97$\frac{1}{3}$ per cent fall below 0.005 millimeter in diameter, the results obtained are very similar to those obtained by Whitney.

TABLE I.—*Bluff loess and sand, probably wind deposited.*

Diameter in millimeters.	Conventional names.	(1370) Gladstone subsoil, 36-96 inches.		(1315) Northern Cass County soil, 1-16 inches.		(1316) Northern Cass County subsoil, 48-120 inches.		(1346) Mason City soil, 2-24 inches.		(1344) Northern Christian County soil, 1-18 inches.	
		Per cent.	Grains per gram.	Per cent.	Grains per gram.	Per cent.	Grains per gram.	Per cent.	Grains per gram.	Per cent.	Grains per gram.
2-1	Fine gravel	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
1-.5	Coarse sand	0.02	0	0.00	0	0.00	0	0.01	0	0.00	0
.5-.25	Medium sand	0.04	6	0.31	46	0.01	1	3.30	465	8.69	1,200
.25-.1	Fine sand	0.84	1,231	2.62	3,799	0.10	142	41.44	57,450	54.87	74,600
.1-.05	Very fine sand	28.17	524,200	8.22	151,400	24.84	447,500	34.76	611,900	29.06	501,400
.05-.01	Silt	49.02	14,260,000	56.63	16,290,000	60.98	17,170,000	10.93	3,007,000	1.45	391,200
.01-.005	Fine silt	5.42	100,900,000	9.65	177,600,000	2.80	50,430,000	2.74	48,250,000	1.27	21,920,000
.005-.0001	Clay	8.31	3,937,000,000	15.34	7,191,000,000	6.15	2,819,000,000	3.87	1,735,000,000	3.66	1,608,000,000
Total mineral matter		91.82	4,052,685,437	92.77	7,385,045,245	94.88	2,887,047,643	97.05	1,786,926,815	99.00	1,630,888,400
Organic matter, water, loss		8.18		7.23		5.12		2.95		1.00	
		100.00		100.00		100.00		100.00		100.00	
Loss by direct ignition		8.18		6.03		8.11		3.64		1.24	

TABLE II.—*Bluff loess, possibly water deposited.*

Diameter in millimeters.	Conventional names.	(1347) East Dubuque soil, 1-15 inches.		(1368) Rock Island soil, 1-6 inches.		(1317) Near Virginia City soil, 4-48 inches.		(1318) Near Virginia City subsoil, 60-120 inches.		(1306) Galatia soil, 1-18 inches.	
		Per cent.	Grains per gram.	Per cent.	Grains per gram.	Per cent.	Grains per gram.	Per cent.	Grains per gram.	Per cent.	Grains per gram.
2-1	Fine gravel	0.00	0	0.00	0	0.00	0	0.00	0	0.00	
1-.5	Coarse sand	0.00	0	0.00	0	0.00	0	0.00	0	0.00	
.5-.25	Medium sand	0.04	46	0.02	3	0.00	0	0.00	0	0.02	
.25-.1	Fine sand	0.74	1,051	0.17	238	0.01	14	0.00	0	0.30	
.1-.05	Very fine sand	30.12	543,000	22.27	397,100	7.68	139,200	8.55	150,300	5.21	
.05-.01	Silt	41.49	11,960,000	51.53	14,370,000	61.85	17,110,000	76.67	21,060,000	57.75	
.01-.005	Fine silt	7.96	143,600,000	9.72	173,400,000	9.60	174,000.000	4.84	85,020,000	12.78	
.005-.0001	Clay	14.44	6,627,000,000	12.08	5,477,000,000	15.15	6,985,000,000	7.10	3,170,000,000	20.36	
Total mineral matter		94.79	6,783,104.057	95.79	5,665,167,341	94.29	7,176,249,214	97.26	3,276,230,300	96.42	
Organic matter, water, loss		5.21		4.21		5.71		2.74		3.58	
		100.00		100.00		100.00		100.00		100.00	
Loss by direct ignition		5.66		4.21		5.87		4.19		6.01	

TABLE III.—*Upland loess, pervious to water.*

Diameter in millimeters.	Conventional names.	(1328) Wyoming soil, 1–15 inches.		(1307) Carrollton soil, 1–15 inches.		(1308) Carrollton subsoil, 24–44 inches.	
		Per cent.	Grains per gram.	Per cent.	Grains per gram.	Per cent.	Grains per gram.
2–1	Fine gravel	0.00	0	0.00	0	0.00	0
1–.5	Coarse sand	0.00	0	0.00	0	0.10	2
.5–.25	Medium sand	0.02	3	0.01	1	0.87	129
.25–.1	Fine sand	0.10	148	0.04	57	1.00	1,462
.1–.05	Very fine sand	6.55	122,900	9.93	180,500	6.17	114,600
.05–.01	Silt	49.20	14,440,000	48.76	13,890,000	62.58	18,170,000
.01–.005	Fine silt	11.21	210,400,000	8.39	153,000,000	8.76	162,700,000
.005–.0001	Clay	23.94	11,440,000,000	23.65	10,970,000,000	12.52	5,916,000,000
Total mineral matter		91.02	11,664,963,051	93.78	11,137,070,558	92.00	6,096,986,193
Organic matter, water, loss		8.98		6.22		8.00	
		100.00		100.00		100.00	
Loss by direct ignition		9.52		6.14		4.16	

TABLE IV.—*Upland loess, almost impervious to water.*[1]

Diameter in millimeters.	Conventional names.	(1321) Greenville soil, 2–15 inches.		(1342) Northern Cumberland County soil, 1–12 inches.		(1345) Western Jefferson County soil, 2–15 inches.		(1343) Moweaqua soil, 2–18 inches.	
		Per cent.	Grains per gram.	Per cent.	Grains per gram.	Per cent.	Grains per gram.	Per cent.	Grains per gram.
2–1	Fine gravel	0.48	1	0.30	1	0.00	0	0.00	0
1–.5	Coarse sand	1.92	35	1.05	18	0.07	1	0.08	1
.5–.25	Medium sand	1.22	178	3.42	483	0.29	42	0.77	113
.25–.1	Fine sand	0.58	65,130	3.30	4,595	0.40	577	0.11	13,110
.1–.05	Very fine sand	5.08	92,790	6.47	114,400	6.38	116,900	4.88	89,280
.05–.01	Silt	59.06	16,870,000	55.48	15,340,000	56.92	16,290,000	52.50	15,020,000
.01–.005	Fine silt	11.09	202,100,000	11.70	206,900,000	12.18	221,800,000	12.15	221,600,000
.005–.0001	Clay	14.12	6,564,000,000	14.90	6,707,000,000	17.06	7,948,000,000	22.10	10,300,000,000
Total mineral matter		93.54	6,783,128,134	96.62	6,929,359,497	93.30	8,186,206,520	93.39	10,536,722,504
Organic matter, water, loss		6.46		3.38		6.70		6.61	
		100.00		100.00		100.00		100.00	
Loss by direct ignition		5.59		3.11		4.49		5.73	

[1] Professor Udden states that the coarse particles found in these samples are usually concretions of iron oxide, instead of sand grains or pebbles. It is probable that the sand seldom exceeds the diameter .25–.1, or the grade called fine sand.

TABLE V.—*Bowlder clays.*[1]

Diameter in millimeters.	Conventional names.	(1334) Charleston soil, 1-18 inches.		(1369) Sheldon soil, 6-12 inches.		(1333) Western Marshall County soil, 1-15 inches		(1327) Knoll, near San Jose, soil, 1-18 inches.		(302) Champaign subsoil, 30-42 inches.	
		Per cent.	Grains per gram.	Per cent.	Grains per gram.	Per cent.	Grains per gram.	Per cent.	Grains per gram.	Per cent.	Grains per gram.
2-1	Fine gravel	0. 13	1	0. 20	1	1. 08	3	0. 00	0	1. 04	2
1-.5	Coarse sand	0. 36	7	0. 71	13	1. 65	31	0. 00	0	1. 98	28
.5-.25	Medium sand	1. 88	284	3. 24	472	6. 45	959	0. 24	35	6. 85	955
.25-.1	Fine sand	2. 10	2, 567	4. 01	5, 750	9. 32	13, 660	0. 57	822	6. 23	8, 753
.1-.05	Very fine sand	3. 73	73, 480	7. 30	132, 900	12. 89	239, 600	8. 54	156, 600	5. 82	104, 100
.05-.01	Silt	44. 28	13, 530, 000	41. 66	11, 860, 000	23. 44	6, 816, 000	44. 63	12, 800, 000	28. 38	7, 907, 000
.01-.005	Fine silt	13. 21	238, 100, 000	13. 33	242, 800, 000	11. 07	206, 000, 000	12. 64	231, 700, 000	15. 46	276, 100, 000
.005-.0001	Clay	21. 70	10, 800, 000, 000	23. 37	10, 830, 000, 000	24. 31	11, 520, 000 000	26. 57	12, 410, 000, 000	30. 00	14, 090, 000, 000
Total mineral matter		87. 41	11, 071, 706, 348	93. 82	11, 084, 819, 136	90. 21	11, 733, 070, 253	93. 19	12, 654, 000, 000	95. 76	14, 374, 100, 8[illegible]8
Organic matter, water, loss		12. 59	....	6. 18	....	9. 79	....	6. 81	....	4. 24	....
Loss by direct ignition		9. 65	....	8. 24	....	8. 16	....	5. 77	....	(?)	....

[1] Professor Udden states that this table does not indicate the amount of coarse material exceeding 2 mm. in diameter, for this was sifted out before the analyses were made.

TABLE VI.—*Miscellaneous.*

Diameter in millimeters.	Conventional names.	(1338) Glacial terrace on Illinois at Chillicothe, soil, 2-18 inches.		(1340) Black gumbo from Mississippi bottoms near East St. Louis, soil, 1-12 inches.		(1332) Sand from Rock River bluff west of Rockford, soil, 1-15 inches.		(1339) Old lake bottom near Chicago, soil, 1-15 inches.		(1325) Elevated part of Driftless Area at Warren, soil, 1-12 inches.	
		Per cent.	Grains per gram.	Per cent.	Grains per gram.	Per cent.	Grains per gram.	Per cent.	Grains per gram.	Per cent.	Grains per gram.
2-1	Fine gravel	0. 16	1	0. 00	0	0. 26	1	0. 30	....	0. 00	....
1-.5	Coarse sand	4. 70	83	0. 00	0	2. 62	48	0. 58	....	0. 00	....
.5-.25	Medium sand	47. 51	6, 755	0. 03	5	23. 52	3, 428	2. 14	....	0. 14	....
.25-.1	Fine sand	13. 55	18, 660	0. 13	194	20. 44	29, 300	3. 48	....	0. 19	....
.1-.05	Very fine sand	3. 01	53, 470	7. 99	151, 400	11. 66	212, 400	4. 72	....	10. 10	....
.05-.01	Silt	16. 82	4, 670, 000	41. 28	12, 230, 000	20. 74	5, 888, 000	28. 12	....	41. 66	....
.01-.005	Fine silt	4. 89	86, 860, 000	10. 33	195, 600, 000	6. 32	115, 100, 000	14. 33	....	11. 97	....
.005-.0001	Clay	5. 61	2, 537, 000, 000	30. 42	14, 680, 000, 000	8. 37	3, 842, 000, 000	36. 52	....	23. 60	....
Total mineral matter		96. 25	2, 628, 608, 968	90. 18	14, 887, 981, 599	93. 85	3, 963, 232, 177	90. 19	....	87. 66	....
Organic matter, water, loss		3. 75	....	9. 82	....	6. 15	....	9. 81	....	12. 34	....
Loss by direct ignition		3. 68	....	9. 82	....	5. 34	....	10. 28	....	13. 12	....

Several chemical analyses of the loess have been made which represent its structure at widely different points. The first four analyses in the table below were made by R. B. Riggs, of the U. S. Geological Survey, in connection with Chamberlin and Salisbury's study of the loess bordering the Driftless Area, and were published in their paper in the Sixth Annual Report of this Survey. No. 1 was taken from the summit of a ridge in the suburbs of Dubuque, Iowa, at a point about 300 feet above the Mississippi River. No. 2 represents a 7-foot stratum of loess lying over brown residuary clay near Galena, Illinois, at about 350 feet above the Mississippi River. No. 3, from Kansas City, Missouri, was chosen as a representative of the most pronounced loessial characters at that locality. No. 4 was taken from near the center of Vicksburg, Mississippi, about 200 feet above the Mississippi River, and probably fairly represents the upper half of the stratum there, but not the lower portion, which seemed heterogeneous. The remaining two analyses were made by Prof. W. A. Noyes for Dr. J. T. Scovell, and are published in the Twenty-first Annual Report of the Indiana Geological Survey. They are designed to illustrate the constitution of the white clay east of the Wabash River, near Terre Haute, Indiana. No. 5 represents the subsoil, the sample being from a depth of about 22 inches. No. 6 represents a sample from a depth of only 10 inches. The samples analyzed by Mr. Riggs were dried at 100° C.; those analyzed by Professor Noyes at 135°.

Table of analyses of loess.

	No. 1.—Dubuque.	No. 2.—Galena.	No. 3.—Kansas City.	No. 4.—Vicksburg.	No. 5.—Near Terre Haute.	No. 6.—Near Terre Haute.
SiO_2	72.68	64.61	74.46	60.69	72.87	79.77
Al_2O_3	12.03	10.64	12.26	7.95	11.25	9.95
Fe_2O_3	3.53	2.61	3.25	2.61	6.75	3.39
FeO	.96	.51	.12	.67	....	....
TiO_2	.72	.40	.14	.52	.95	.70
P_2O_5	.23	.06	.09	.13	....	....
MnO	.06	.05	.02	.12	....	....
CaO	1.59	5.41	1.69	8.96	.69	.67
MgO	1.11	3.69	1.12	4.36	1.06	.26
Na_2O	1.68	1.35	1.43	1.17	.39	1.08
K_2O	2.13	2.06	1.83	1.08	2.26	2.05
H_2O (*a*)	2.50	2.05	2.70	1.14	4.24	2.55
CO_2	.39	6.31	.49	9.63	....	....
SO_3	.51	.11	.06	.12	....	....
C	.09	.13	.12	.19	....	....
	100.21	99.99	99.78	99.54	100.44	100.42

a Contains H of organic matter in Nos. 1-4.

FOSSILS.

From the time of the earliest recognition of the loess in the Mississippi Basin the presence of fossils has been mentioned as a peculiarity of the deposit. These fossils are present, not as ingredients of a mixture, like the wood or other organic remains found in bowlder clay (whose life was independent of the deposits in which they are embedded), but as a fauna representing the life of the region during the progress of the accumulation of the deposit and dwelling upon it or in it.

The loess fossils are found in greatest abundance along the immediate borders of the main valleys where the loess attains its greatest thickness, notably along the Mississippi, the Illinois, and the Wabash. They occur from the top to the bottom of the deposit and bear clear evidence of having lived during its deposition. Along the smaller valleys of the region they are rarely found. On the interfluvial tracts but few fossils have been found at a distance greater than 5 miles back from the borders of the main valleys. The most notable exception is in the thickened loess border south of the Green River Basin, where the loess is thought to have been deposited along the Iowan ice front, though here they are far less numerous than along the main valleys. Fossils are also distributed more widely along the Sangamon than along other tributaries of the Illinois, being found as far back as the vicinity of Springfield.

The cause for the scarcity of fossils along the small streams and in the interfluvial tracts can as yet scarcely be decided. It is not known whether they have been destroyed there by subsequent leaching and weathering or were never present. Professor Shimek, as indicated more fully below, has found that in eastern Iowa the living representatives have about the same distribution in relation to streams as those embedded in the loess, and he infers that the loess fossils were never present in abundance at a great distance from the main valleys.

The most abundant and widely distributed fossils are mollusks, of which terrestrial species predominate over aquatic. By far the most common mollusk is *Succinea avara*, a form which is now found in swampy places as a rule, but which occasionally occurs in dry situations. Shimek regards this as a strictly terrestrial rather than a semiaquatic form. The tables given below serve to indicate the proportion of species of terrestrial and aquatic forms. The shells of a few unios and other strictly fluviatile

mollusks have been reported from the loess, but closer investigation tends to render doubtful their occurrence in unmodified loess. In other cases, notably in the deposits near Freeport, from which collections have been made by Hershey, the relation to the loess is not clearly determined and the deposits may prove to be entirely independent of the loess deposition.

Concerning the mammalian remains reported from the loess, it is necessary to state that their relation to the loess deposition is, in most if not in all cases, very vaguely determined. The remains of a mammoth, found near Davenport, and reported by W. H. Pratt,[1] were apparently from near the base of the loess and just above the Sangamon soil, which is there represented by a bed of peat and soil 3 feet in thickness. Possibly the remains were derived from the Sangamon soil horizon and redeposited in the basal portion of the loess. The remains of a deer are reported by Witter[2] to have been found in the loess near Muscatine. A fine fragment of the jaw of a mastodon is reported by Worthen[3] to have been found just above the city of Alton, Illinois, beneath 30 feet of loess, and separated from the underlying limestone by 2 or 3 feet of local drift. Worthen also reports[4] the occurrence of the remains of extinct mammalia in brown clays overlying the limestones, as well as in the crevices of the limestone in the driftless region of northwestern Illinois. Whether these are beneath or within the loess deposit which covers that region has not been ascertained.

As yet the molluscan fossils have been collected and specifically identified in but a few localities within the region under discussion. Since there is some variation from place to place, the identifications of each locality are represented. Those in List 1, from Savanna, Illinois, represent the fauna in the southern portion of the Driftless Area. In addition to these, *Helicodiscus lineatus* Anth. has been found near Galena and *Limnophysa humilis* Say has been found on the heights east of Prairie du Chien. These are thought by Salisbury to be in unmodified loess, and are separated from a list of fossils found in the terraces of streams traversing the Driftless Area.[5]

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[1] Proc. Davenport Acad. Sci., Vol. I, 1876, pp. 96–99. Also Geol. of Iowa, by C. A. White, Vol. I, 1870, p. 119.

[2] Proc. Iowa Acad. Sci., Vol. I, 1880, p. 16. Also Eleventh Ann. Rept. U. S. Geol. Survey, 1890, p. 471.

[3] Geol. of Illinois, Vol. I, 1866, pp. 38 and 315.

[4] Ibid., p. 39.

[5] Sixth Ann. Rept. U. S. Geol. Survey, pp. 285 and 286.

The Davenport fossils are apparently from the unmodified loess along the west bluff of the Mississippi, as are also those from Burlington, Iowa. The list from Moline, Illinois, is from specimens gathered on the level upland lying between the Rock and Mississippi rivers. A loess-like silt carrying fossils has been found beneath the glacial deposits in that vicinity. The fossils, so far as identified in this lower silt, are strikingly similar to those found in the surface deposit.

The list from Muscatine, Iowa, contains, in addition to the usual loess fauna, several species of Unio. Unfortunately the evidence is not clear concerning the condition of the bed of loess in which these Unio shells was found. It is Professor Witter's present opinion that the loess had suffered some disturbance, thus leaving it an open question whether the shells are as ancient as that deposit.

The fossils noted in the list from near Freeport are stated by Hershey to have been secured from under a bed of loess in a blue-green silt, separating the loess from the underlying gravel. He further states that the gravel is made up in part of erratics, and is, therefore, not preglacial in age. This gravel and the overlying silt are described by Hershey under the name "Florencia formation,"[1] and are referred to an interglacial stage between the loess deposition (which he correlates with the Iowan glaciation) and a preceding period of glaciation now provisionally referred to the Illinoian. It is stated that great care was taken in securing the shells, because it was early recognized that a fauna of very similar facies occurs in the modern alluvial deposits of that region. It is also stated that this blue-green silt is overlain with perfect conformity by the basal member of the Iowan loess series, a feature which leads the present writer to question whether it should be separated from the loess series. However, the striking contrast between the fauna of this deposit and that usually displayed by the loess and the striking similarity to the alluvial fauna of that region, should have weight in determining the classification.

The list from Virginia, Illinois, is made up entirely of a collection in the office of Dr. J. F. Snyder, at Virginia, who also made the identifications.

[1]Amer. Jour. Sci., 4th series, Vol. IV, 1897, pp. 90–98.

Lists of loess fossils.

	Names heretofore commonly used.	Names in Pilsbry and Johnson's check list of terrestrial mollusks for 1898.
List I. From Savanna, Illinois. (Collected by R. D. Salisbury and identified by R. E. Call.) *a*	Patula striatella (Anth.) Morse	Pyramidula striatella (Anth.) Pils.
	Patula strigosa var. Cooperi W. G. B.	Pyramidula strigosa iowensis Pils.
	Succinea avara Say	Succinea avara Say.
	Succinea obliqua Say	Succinea obliqua Say.
List II. From Davenport, Iowa. (Reported by W. H. Pratt.) *b*	Succinea avara Say	Succinea avara Say.
	Succinea obliqua Say	Succinea obliqua Say.
	Helicina occulta Say	Helicina occulta Say.
	Pupa fallax Say	Leuchocheila fallax (Say) Try.
	Patula striatella (Anth.) Morse	Pyramidula striatella (Anth.) Pils.
List III. From Davenport, Iowa. (Collected by J. A. Udden; identified by C. T. Simpson.)	Succinea avara Say	Succinea avara Say.
	Succinea luteola Gld	Succinea luteola Gld.
	Succinea lineata ? W. G. B	Succinea grosvenorii Lea.
	Ferussacia subcylindrica (L.) Binn.	Cochlicopa lubrica (Müll.) P. & J.
	Patula striatella (Anth.) Morse	Pyramidula striatella (Anth.) Pils.
	Helicodiscus lineatus (Say) Morse.	Helicodiscus lineatus (Say) Morse.
	Helicina occulta Say	Helicina occulta Say.
	Pupa alticola Inger	Sphyradium edentulum alticola (Inger.) P. & J.
List IV. From Muscatine, Iowa. (Identified by F. M. Witter; revised by B. Shimek.) *c*	Patula striatella (Anth.) Morse; also Helix striatella.	Pyramidula striatella (Anth.) Pils.
	Zonites fulvus (Drap.) Binn.; also Helix fulva.	Conulus fulvus (Drap.) Müll.
	Vallonia pulchella (Müll.) Binn.; also Helix pulchella.	Vallonia pulchella (Müll.) Binn. *d*
	Helicodiscus lineatus (Say) Morse; also Helix lineata.	Helicodiscus lineatus (Say) Morse.
	Patula strigosa cooperi W. G. B.; also Helix cooperi.	Pyramidula strigosa iowensis Pils.
	Pupa pentodon (Say) Gld	Bifidaria pentodon (Say) Sterki.
	Pupa corticaria Say	Bifidaria corticaria (Say) Sterki.
	Pupa muscorum L	Pupa muscorum L.
	Pupa alticola Inger	Sphyradium edentulum alticola (Inger.) P. & J.
	Succinea avara Say	Succinea avara Say.

a Published in Sixth Ann. Rept. U. S. Geol. Survey, 1885, p. 285.
b Published in Proc. Davenport Acad. Sci., 1876, pp. 96-99; also in Eleventh Ann. Rept. U. S. Geol. Survey, 1890, p. 471.
c Published in Proc. Iowa Acad. Sci., 1880, p. 16; also in Eleventh Ann. Rept. U. S. Geol. Survey, 1890, p. 471.
d See footnote *a* on next page.

Lists of loess fossils—Continued.

	Names heretofore commonly used.	Names in Pilsbry and Johnson's check list of terrestrial mollusks for 1898.
List IV. From Muscatine, Iowa. (Identified by F. M. Witter; revised by B. Shimek.)—Continued.	Succinea obliqua Say	Succinea obliqua Say.
	Helicina occulta Say	Helicina occulta Say.
	Limnaea humilis Say	
	Unio ebenus Lea	
	Unio ligamentinus Lea	
	Unio rectus Lam	
	Campeloma subsolidum (Anth.) Call; also Melantho subsolida.	
	Margaritana confragosa Say.	
List V. From Burlington, Iowa. (Collected by Frank Leverett; identified by C. T. Simpson.)	Succinea obliqua Say	Succinea obliqua Say.
	Succinea lineata W. G. B	Succinea grosvenorii Lea.
	Helicina occulta Say	Helicina occulta Say.
	Patula strigosa cooperi W. G. B.; also Pyramidula strigosa.	Pyramidula strigosa iowensis Pils.
	Pyramidula striatella Anth.; also Patula striatella (Anth.) Morse.	Pyramidula striatella (Anth.) Pils.
	Pyramidula perspectiva (Say) Binn.	Pyramidula perspectiva (Say) Pils.
List VI. From near Freeport, Illinois. (Collected by Oscar Hershey; identified by W. H. Dall.) *b*. 1. Terrestrial species.	Vallonia costata Müll.; also Vallonia pulchella var. costata.	Vallonia costata Müll. *a*
	Vallonia perspectiva Sterki	Vallonia perspectiva Sterki.
	Zonitoides arboreus Say; also Zonites arboreus (Say) Binn.	Zonitoides arboreus (Say) P. & J.
	Zonites radiatulus Ald; also Hyalina radiatula Ald.	Vitrea hammonis (Ström.) P. & J.
	Zonites minusculus Binn; also Hyalina minuscula Binn.	Zonitoides minusculus (Binn.) P. & J.
	Zonites indentatus (Say) Binn; also Hyalina indentata Say.	Vitrea indentata (Say) P. & J.
	Patula alternata (Say) Binn; also Pyramidula alternata Say.	Pyramidula alternata (Say) Pils.
	Patula striatella (Anth.) Morse; also Pyramidula striatella (Anth.) Morse.	Pyramidula striatella (Anth.) Pils.
	Helicodiscus lineatus (Say) Morse	Helicodiscus lineatus (Say) Morse.
	Stenotrema hirsutum (Say) Try.; also Polygyra hirsuta Say.	Polygyra hirsuta (Say) Pils.

a It is now difficult to ascertain the correctness of the earlier identifications of the species of *Vallonia*. The species were all formerly referred to *V. pulchella* or to *V. pulchella* var. *costata*, but Dr. Sterki's investigations have brought to light a greater number of species than was at first recognized. Most of the forms formerly called *V. pulchella* from the loess west of the Mississippi are *V. gracilicosta*, and those called *V. pulchella* var. *costata* are at least in part *V. parvula* Sterki. This difficulty in making the identifications does not in any manner affect the general discussion, as all the species are strictly terrestrial in habit. (Shimek.)

b Published in Am. Jour. Sci., 4th series, Vol. IV, 1897.

Lists of loess fossils—Continued.

	Names heretofore commonly used.	Names in Pilsbry and Johnson's check list of terrestrial mollusks for 1898.
List VI. From near Freeport, Illinois. (Collected by Oscar Hershey, identified by W. H. Dall.) 1. Terrestrial species—Continued.	Strobilops virgo Pils	Strobilops virgo Pils.
	Pupa contracta Say	Bifidaria contracta (Say) Sterki.
	Pupa corticaria Say	Bifidaria corticaria (Say) Sterki.
	Pupa armifera Say	Bifidaria armifera (Say) Sterki.
	Pupa holzingeri Sterki	Bifidaria holzingeri (Sterki) Sterki.
	Vertigo tridentata Wolf	Vertigo tridentata Wolf.
	Succinea avara Say	Succinea avara Say.
	Carychium exiguum (Say) Gld	Carychium exiguum (Say) Gld.
	Carychium exile (?) Pils	Carychium exile Pils.
2. Fluviatile species (gill-bearing univalves).	Pleurocera subulare (Lea) Try	
	Campeloma decisa (Say) Call	
	Bythinella tenuipes (Coop.) Binn.	
	Amnicola cincinnatiensis Anth	
	Amnicola porata (Say) Hald	
	Somatogyrus depressus (Try.) Gill.	
	Valvata tricarinata Say	
3. Fluviatile bivalves (some occasionally in ponds).	Pisidium compressum Prime	
	Pisidium cruciatum Sterki	
	Pisidium fallax Sterki	
	Pisidium punctatum Sterki	
	Pisidium variabile Prime	
	Pisidium virginicum Gmel	
	Pisidium walkeri Sterki	
	Sphærium stamineum (Con.) Prime	
	Sphærium striatinum (Lam.) Prime	
	Sphærium simile Say	
	Sphærium solidulum Prime	
4. Pond species air-breathing (some fluviatile).	Planorbis parvus Say	
	Planorbis bicarinatus Say	
	Physa heterostropha Say	
	Segmentina armigera (Say) Ad	
	Limnaea humilis Say	
	Ancylus tardus Say	
	Ancylus rivularis Say	
	Ancylus parallelus Hald	
List VII. From Moline, Illinois. (Collected by J. A. Udden; identified by C. T. Simpson.)	Succinea avara Say	Succinea avara Say.
	Succinea luteola Gld	Succinea luteola Gld.
	Succinea obliqua Say	Succinea obliqua Say.
	Helicina occulta Say	Helicina occulta Say.
	Patula striatella (Anth.) Morse; also Pyramidula striatella.	Pyramidula striatella (Anth.) Pils.

Lists of loess fossils—Continued.

	Names heretofore commonly used.	Names in Pilsbry and Johnson's check list of terrestrial mollusks for 1898.
List VII. From Moline, Illinois. (Collected by J. A. Udden; identified by C. T. Simpson.)—Continued.	Pupa alticola Inger	Sphyradium edentulum alticola (Inger.) P. & J.
	Pupa muscorum L	Pupa muscorum L.
	Pupa pentodon (Say) Gld	Bifidaria pentodon (Say) St.
	Vallonia pulchella (Müll.) Binn	Vallonia pulchella (Müll.) Binn.
List VIII. From Virginia, Illinois. (Collected and identified by J. F. Snyder.)	Patula striatella (Anth.) Morse; also Helix striatella.	Pyramidula striatella (Anth.) Pils.
	Helix orbiculata? Perhaps Helicina orbiculata or Helicina occulta Say.	?
	Macrocyclis concava (Say) Morse; also Helix concava.	Circinaria concava (Say) P. & J.
	Mesodon clausa (Say) Try.; also Helix clausa.	Polygyra clausa (Say) Pils.
	Helix solitaria? Perhaps Pyramidula strigosa iowensis Pils.	?
	Stenotrema monodon (Rack.) Morse; also Helix monodon.	Polygyra monodon (Rack.) Pils.
	Mesodon multilineata (Say) Try; also Helix multilineata.	Polygyra multilineata (Say) Pils.
	Mesodon pennsylvanica (Green) Try; also Helix pennsylvanica.	Polygyra pennsylvanica (Green) Pils.
	Patula alternata (Say) Binn.; also Helix alternata.	Pyramidula alternata (Say) Pils.
	Arionta exarata Pfeiff.; also Helix exarata.	Epiphragmophora exarata (Pfeiff.) P. & J.
	Succinea obliqua Say	Succinea obliqua Say.
	Limnaea humilis Say.	
	Bulinus dealbatus; probably Bulinus hypnorum or Bulimus dealbatus.	Bulimulus dealbatus ?.

Professor Shimek has furnished the following notes in reference to the fossils given in the foregoing lists.

Of the foregoing lists I, II, III, IV (except the last five species), V, and VII contain typical loess fossils and may be considered together. The species mentioned are the following:

1. Conulus fulvus (Drap.) Müll.
2. Helicodiscus lineatus (Say) Morse.
3. Pyramidula striatella (Anth.) Pils.
4. Pyramidula strigosa iowensis Pils.

5. Pyramidula perspectiva (Say) Pils.
6. Vallonia pulchella (Müll.) Binn.[1]
7. Cochlicopa lubrica (Müll.) P. & J.
8. Leuchochila fallax (Say) Try.
9. Pupa muscorum L.
10. Bifidaria corticaria (Say) St.
11. Bifidaria armifera (Say) St.
12. Bifidaria pentodon (Say) St.
13. Sphyradium edentulum alticola (Inger.) P. & J.
14. Succinea avara Say.
15. Succinea obliqua Say.
16. Succinea luteola Gld.
17. Succinea grosvenorii Lea.
18. Helicina occulta Say.
19. Limnaea humilis Say.

Of these species all but the last one are strictly terrestrial in habit. One species, No. 5, rare in northern loess, is very common in the loess of Mississippi. The last species, No. 19, is an aquatic pulmonate, occurring in pockets or restricted parts of the loess as though deposited at the edge of a pool or pond.[2] As for the last five species in List IV this may be said: They are strictly fluviatile. There are reasons for believing, however, that they did not come from unmodified loess,[3] and morever they and their relatives have thus far not been found in any other locality except in what is clearly modified loess. There still remain lists VI and VIII which will be discussed separately.

The fossils of List VI are in all probability from alluvium, and not from the loess, for two reasons—one positive, the other negative:

1. The list very closely resembles lists of species found in alluvium along several streams, notably along Rock River near its mouth, along the Cedar River at Cedar Rapids and near Mount Vernon, and along the Iowa near Iowa City.[4] It will be observed that the species in this list are grouped according to habit. The first section or group contains the terrestrial forms, nearly all of which also occur in the loess. All now live on alluvial bottom lands or the adjacent hills, and their shells are often washed down for short distances.

2. The list in its entirety is unlike any undoubted loess fauna which has been reported by trustworthy observers.

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[1] See footnote *a* on p. 169.

[2] See discussion of Limnaea by Shimek, in Proc. Iowa Acad. Sci., Vol. V, 1898, pp. 34, 35.

[3] Professor Shimek reached this conclusion after a conversation with Professor Witter.

[4] The Rock River list was published in Iowa University Bulletin, Vol. II, pp. 170 and 171.

The shells in List VIII are for the most part terrestrial, and most of them occur in ordinary loess more or less commonly. The list is striking because of the number of large Helices and the absence of small forms, in this respect being more like the southern loess.

It is probable that the "*Helix solitaria*" of the list is our *Pyramidula strigosa iowensis*, a frequent loess fossil. *Helix orbiculata* may really be *Helicina orbiculata*, a species much like our *Helicina occulta*, to which the specimens may possibly belong. *Helicina orbiculata*, however, is common in the loess of Natchez. *Helix exarata*, of this list, is a west coast species, and if the determination is correct it must have been transported a great distance overland. It is out of place. As for the remaining species, all the species of "Helix" are strictly terrestrial. *Succinea obliqua* and *Limnaea humilis* have already been discussed.

Bulinus dealbatus should be either *Bulimus dealbatus*, a southern terrestrial species, or it is *Bulinus hypnorum*, a pond snail like Limnæa and Physa in habit. *Valvata tricarinata* and *Vivipara intertexta* are fluviatile, or may be found in ponds. It will be of interest to ascertain their relation to the other fauna as to abundance and distribution. On the whole the shells are unlike those of our northern loess, but differ still more from the southern loess fauna, which, so far as I have been able to determine, is absolutelv without aquatic forms.

"To these lists," writes Professor Shimek, "I can add but few names. From Davenport I have specimens of *Limnæa humilis*; from Muscatine *Zonitoides minusculus* (Binn.) P. & J.; from Moline *Limnæa humilis* Say, and *Polygyra clausa* Say."

Since the foregoing statement was written Professor Shimek has received several collections of fossils from Prof. J. A. Udden, and reports upon them as follows:

From Division street, Davenport, Iowa, near base of loess. Collected by Prof. J. A. Udden:

Helicina occulta Say.
Succinea avara Say.
Sphyradium edentulum alticola (Inger.) P. & J.
Pyramidula striatella (Anth.) Pils.
Bifidaria pentodon (Say) Sterki.
Limnæa palustris Müll. (fragment.)
Limnæa caperata Say.
Sphærium—fragment of a valve.

The last three species in this list are pond species.

"From loess in bluff above Hershey avenue, Muscatine, Iowa." (Prof. J. A. Udden's note.)

Helicina occulta Say.
Polygyra multilineata (Say) Pils. (Probably this species; specimen young.)
Polygyra monodon (Rack.) Pils.
Strobilops virgo Pils.
Bifidaria pentodon (Say) St.
Pupa muscorum L.
Cochlicopa lubrica (Müll.) P. & J.
Pyramidula alternata (Say) Pils.
Pyramidula perspectiva (Say) Pils.
Pyramidula striatella (Anth.) Pils.
Succinea obliqua Say.
Succinea avara Say.
Succinea ovalis Gld.
Limnæa caperata Say.
Valvata sincera Say.

Succinea ovalis, of which one specimen was submitted, lives on mud flats, etc.; *Limnæa caperata* and *Valvata sincera* are pond species—the latter now for the first time reported from the loess; all the others are terrestrial

From base of loess in bluff of Mill Creek, about 5 miles south of Milan, Illinois, collected by Prof. J. A. Udden:

Succinea avara Say.
Limnæa stagnalis L. A fragment, probably this species.
Limnæa reflexa Say.
Planorbis albus Müll. Not heretofore reported.
Planorbis parvus Say.
Valvata tricarinata Say.
Valvata sincera Say.
Pisidium ———. Five fragments of valves, probably belonging to two species.

With the exception of the first, all of these are pond species.

These lists, remarks Shimek, are of special interest because of the comparatively large number of pond species which they contain. The presence of these forms, however, does not strengthen the aqueous theory of loess formation. Both the distribution of these aquatic forms in the loess and their habits in life indicate this. They do not represent the average loess-fauna even of the Mississippi River, but occur in restricted areas and seem to have been collected chiefly from the lower part of the loess. In habits these forms are pond-inhabiting, air or water breathers, which do not require or favor large bodies of water, but which flourish in smaller ponds.

Their presence rather only serves to emphasize my contention that the fauna of the loess is in all cases very similar to the fauna of the surface in the same region. Pond species are more abundant and of greater variety in eastern Iowa and Illinois, especially along river courses, than they are westward. Probably during the deposition of the loess the same conditions existed, and the agency chiefly concerned in the work of deposition, whether wind or water, buried more of these aquatic species in the eastern loess, simply because there were more of them, proportionately, upon the surface. The following quotation[1] bears upon this point:

No distinction can be made between the origin of eastern and western loess. The finer quality and lesser thickness of the former rather suggest that there had been more moisture (i. e., a shorter dry period during each year) and hence less dust; that the winds were less violent, and that there were greater areas completely covered with vegetation, this resulting in the necessity of transporting dust much greater distances, which would therefore be finer.

It should be borne in mind that the above noted differences between the regions in question actually exist to-day. There is more rain—there are larger areas closely covered with vegetation, and less violent winds prevail in eastern Iowa and eastward—and considering the position of mountain chains and seas, the same differences must have existed for a long time. That they did exist, during the deposition of the loess, is also indicated by the proportionately somewhat larger number of species in the eastern loess which prefer or require moist habitats. But the fauna of the eastern or Mississippi River loess is essentially a terrestrial fauna. The great fluviatile groups, now everywhere common in the streams of eastern Iowa, are wanting in the loess, and the few fossil aquatic species are such as to-day prefer ponds, and are often found even in those which dry up during the summer.

In addition to these notes furnished by Professor Shimek, a few remarks are taken from his discussion of the loess in a recent paper published in Proceedings of the Iowa Academy of Sciences:[2]

The majority of the geologists who have given attention to the loess of the Mississippi Valley have ascribed its deposition to water in lakes or sluggish streams Some have also contended that this occurred in a glacial climate, or at least in a climate much colder than that of to-day in the same region.

That fresh water has been regarded as the agent of deposition is due in no small degree to the belief that a very considerable portion of the species and individuals found in the deposit consist of aquatic or semiaquatic forms, although the fact has long been recognized that terrestrial species prevail. There is, however, absolutely nothing in the loess fauna to indicate that the loess land surfaces were more moist, or to any extent more widely or more deeply covered with waters, than are the surfaces

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[1] Shimek: Proc. Ia. Acad. Sci., vol. vi, 1898, p. 110.

[2] Proc. Iowa Acad. Sci. for 1897, Vol. V, 1898, pp. 32–45.

of Iowa and Nebraska to-day—the evidence, if it suggests any difference, indicating rather less moisture than is found in eastern Iowa at the present time. This statement, which can not be too strongly emphasized, is based upon the study of the modern mollusks of Iowa and Nebraska and their fossil prototypes, extending over a period of nearly twenty years. * * *

Moreover the molluscan loess-fauna of any region is on the whole like the modern fauna of the same region. For example, Binney reports a number of species from the "post-pliocene" (evidently the loess) of the lower Mississippi Valley, of which eleven are southerly species, and all now live in the same region. Call reports[1] fifteen species from the loess of Arkansas, three of them included in the southerly list, and all belong to the modern molluscan fauna of that State. The same is true of the faunas of Iowa and Nebraska, as has been stated.

This does not indicate transportation from a distance. It is interesting and noticeable that for the most part the species of the loess are common over the same region now. There are some exceptions, for there have been changes no doubt, but these changes, as indicated by the distribution of the shells, are no greater than may now be observed in any limited region in the course of a few years. Species are sometimes disposed to appear, disappear, and reappear in a surprising manner in a given locality, and if we may judge from the vertical distribution of the fossil shells, the same was true during the deposition of the loess.

The horizontal distribution of the fossils is likewise such that it suggests at once that they are deposited in situ.

As there are surface areas to-day which have no mollusks, lying in close proximity to those on which mollusks are abundant, so there are deposits of loess without fossils adjacent to those which are fossiliferous. As the lands, high or low, lying adjacent to larger streams have greater numbers of mollusks to-day than the outlying prairies, so the loess bordering these streams is usually much more fossiliferous than that which covers more remote areas, but the distribution of the fossils is not in bands, as if drifted, but is similar to that of the modern specimens at the surface.[2] Summing up the evidence of the fossils, we may assert that it points to conditions not unlike those which exist to-day, and that geologists in seeking for the cause and manner of the deposition of the loess must give up the assumption of widely submerged areas over which fossiliferous loess now occurs, and of a cold climate.

MODE OF DEPOSITION.

The mode of deposition of the loess still remains one of the most puzzling problems of Pleistocene geology. Both the æolian and aqueous hypothesis have strong adherents among the students of the Mississippi Valley portion as well as of other portions of this formation. The students of the Mississippi Valley portion, however, all grant that the influence of wind has been important, and probably all would concede that water has

[1] Geol. Survey Ark., Vol. II, pp. 49, 165, and 166.

[2] In a recent paper Shimek has discussed more fully the distribution of loess fossils: Jour. Geol. Vol. VII, 1899, pp. 122–140. Also Proc. Iowa Acad. Sci., Vol. VI, 1898, pp. 98–113.

been influential. The division of opinion, therefore, is concerned with the relative importance of wind and water in the distribution of the loess. The question of the influence of the atmosphere as an agent of erosion, transportation, and sedimentation has been very carefully examined by Udden, with the result of showing that a large part of the loess may have been deposited through this agency.[1] In a recent paper[2] Chamberlin has discussed the peculiarities of distribution and considered the difficulties attending the application of either hypothesis to the entire deposit. The distribution of the thickest and coarsest loess along the main valleys, with its great extent down the Mississippi, creates a strong conviction "that the deposition of the loess was in some vital way connected with the great streams of the region." The abrupt border of the loess at the edge of the Iowan drift sheet both in Illinois and Iowa gives it a "more or less direct genetic relationship with the ice." The graduation of loess into glacial clays "further tends to confirm the association of the loess with glacial action." The influence of glacial action is also shown in the presence of silicates which are decomposable under prolonged weathering and of calcium and magnesian carbonates, none of which can be supposed to come from the residuary clays. An illustration from the Lower Mississippi Valley is given which strengthens this inference:

> Above the Lafayette gravels and below the loess there is a stratum of silt which does not habitually contain the characteristic silicate particles of the loess. This stratum has been by most observers associated with the loess, but it is separated from it by a soil horizon, as abundantly affirmed by the observations of Salisbury and the writer. On the other hand, it graduates more or less freely into the Lafayette sands and gravels. The stratum is, as we interpret it, the last deposit of the Lafayette stage. It is a typical finishing deposit succeeding a fluvial sand and gravel. Now this has special significance in this relationship in that it shows that in the stage closely preceding the loess deposition the Mississippi did not lay down silts of the same constitution as the loess. The inference, therefore, is that the loess is not simply a fluvial silt brought down from the surface of the river basin, nor common wind drift borne into it, but that it had a special origin connected with the glacial action which was competent to supply precisely the kind of silt of which the loess was made.

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[1] The main results of Udden's studies are presented in the following papers: "Erosion, transportation, and sedimentation performed by the atmosphere": Jour. Geol., Vol. II, 1894, pp. 318-331. "Loess as a land deposit": Bull. Geol. Soc. Amer., Vol. IX, 1897, pp. 6-9. "The mechanical composition of wind deposits," Augustana Library Publications, No. 1, 1898. Lutheran Augustana Book Concern, Rock Island, Illinois.

[2] Supplementary hypothesis respecting the origin of the loess of the Mississippi Valley, by T. C. Chamberlin: Journ. Geol., Vol. V, 1897, pp. 795-802.

The leading difficulties cited by Chamberlin as attending the hypothesis that the loess is simply an outwash of glacial grindings distributed by glacio-fluvial waters, are its vertical distribution and the presence of shells of land mollusks. "The extreme vertical range is not far from 1,000 feet. The range within a score of miles is frequently from 500 to 700 feet." In its interfluvial phase it mantles an undulatory surface and apparently reaches a greater elevation on the east than on the west side of the main valleys. It is difficult to bring its border into strict accord with a horizontal plain as required by the lacustrine and marine phases of the hypothesis, or even into a consistent gradient as required by the fluvial phase, without an arbitrary warping of the surface. It seems also extremely difficult to conceive how a great flood which had the ice sheet for its northern border could have been peopled so widely with land mollusks. In view of these difficulties, Chamberlin proposes to divide the influence of wind and water as follows. He adopts the glacio-fluvial hypothesis as the fundamental explanation, assuming, (*a*) the presence of the Iowan ice at the chief stage of deposition; (*b*) a very low slope of the land and consequent wide wandering of the glacial waters; (*c*) the development of extensive flats over which the glacial silts were spread; (*d*) great periodic extension of glacial waters caused by (1) periods of warm weather in the melting season, and (2) by warm rains. He considers it probable that the periodic extensions of the floods were not always destructive to vegetation over the flat region, and that land mollusks and other animals dependent upon the vegetation may have found temporary retreat from the flood on the taller vegetation. Upon the retreat of the waters, extensive silt-covered flats would become exposed to the sweeping influence of the wind, and when dried the silt would be borne in great quantities over the adjoining uplands.

This hypothesis demands an accommodation between the breadth of the fluvial deposits and the extent and massiveness of the æolian deposits, for a restriction of the glacial floods to narrow channels would render the sweeping ground for the winds too limited in area to supply material for the great mantle of silt found on the uplands. In proportion as the river work is narrowed the wind work is expanded. It follows that the æolian factor will cut away its own ground if pushed too far. It is further urged that the æolian deposits are measured not by the quantity of silt borne by the winds and lodged on the surface, but by the *difference* between such

lodgment and the erosion of the surface. "Erosion is ordinarily more than a match for the dust accumulations. The conditions must have been extraordinary which would give a dust deposition sufficient to supply erosion and still leave such a large residuum as the loess mantle implies. The unleached and unweathered nature of the body of the loess is specially in point here. These considerations warn us of the theoretical danger of too greatly circumscribing the fluvial action."[1]

An undue extension of the fluvial hypothesis is thought to be antagonistic to the existence of molluscan life and also encounters the topographical and physical difficulties previously urged. In conclusion Chamberlin calls attention to the efforts made by himself and colleagues to find criteria of discrimination between aqueous and æolian loess, and remarks that "while individual types of both deposits are not difficult to find, a criterion or series of criteria of general applicability which shall distinguish the two and assign to each its appropriate part are wanting."

Turning now to the region under discussion in order to test the applicability of the hypothesis suggested by Chamberlin, it is found that the variations in level are sufficiently great to put the hypothesis of fluvial deposition to severe tests, though they are not so conspicuous as in bordering districts on the east or west. The district covered by the Illinois glacial lobe is largely embraced between the levels of contours lying 800 and 500 feet above tide, the general elevation in the northern portion of the district being about 800 feet and the southern portion about 500 feet. This descent of 300 feet in passing from the northern to the southern portion of the State is about the same as the fall of the Mississippi River along its western borders. The Mississippi Valley, however, is cut to an average depth of about 200 feet below the bordering uplands. A small portion of northern Illinois slightly exceeds 1,000 feet and portions of southeastern Illinois and southwestern Indiana fall below 400 feet, thus giving a range of fully 600 feet within the limits of the State, aside from the deepening of valleys since the loess deposition. The most conspicuous abrupt variation in elevation of loess-covered districts is found in the southern end of the State, where, as above noted, a ridge rises 300 feet or more above border tracts. A few conspicuous reliefs occur along the border of the Mississippi in northwestern Illinois and in the portion south from Quincy.

[1] For a partial dissent from Chamberlin's views see Udden: Bull. Geol. Soc. Amer., Vol. IX, 1897, pp. 7–8; also Shimek: Proc. Iowa Acad. Sci., Vol. VI, pp. 109–110, and Jour. Geol., Vol. VII, 1899, p. 135.

The streams of southern Illinois are flowing in broad shallow troughs in which a rise of 30 or 40 feet would cause an expansion of the stream to a width of several miles. Such is notably the case in the valleys of the Kaskaskia, Big Muddy, Saline, Little Wabash, Bon Pas, and Embarras rivers. The same is true of the lower course of the Wabash and of a portion of White River below Worthington and of the lower course of East White River. The valleys of western Illinois and southeastern Iowa were apparently, at the time of the loess deposition, cut down only to a level 50 to 100 feet above the present level of the streams, as is shown by the level of the lowest loess-capped terraces. This, however, is 50 to 100 feet below neighboring uplands. A rise similar to that which would cause extensive flooding in southern Illinois would not carry them beyond the limits of their present valley bottoms. Unless, therefore, a rise much greater than 30 or 40 feet be assumed, the glacial waters would have been confined to the immediate channels of the larger streams, and, as urged by Chamberlin, the sweeping ground of silt for the winds to work upon would have been too restricted to supply the great mantle of silt covering the neighboring uplands. The problem here puts both the fluvial and æolian hypotheses to severe test. It seems necessary to grant a rise of water sufficient to overspread the neighboring uplands in order to afford a sufficient sweeping ground to supply material for the portion of the loess mantle found along the divides. In southeastern Iowa and neighboring portions of Illinois and Missouri a rise of 100 to 150 feet would be necessary to cause a wide expansion of the glacial streams. However, with the assumed low altitude of the loess-covered region, and resulting low gradient of the streams, a depth of 100 feet of water over the main valleys may be within the limits of probability. A rise of this amount in the southern Illinois district would carry the waters over the greater part of the interfluvial districts.

The evidence relied upon to demonstrate the agency of water in connection with the deposition of the loess and associated silts is the presence of material too coarse to have been transported by wind, and the occurrence of water-laid beds of sand, silt, or coarser material. Such evidence must be weighed very carefully to guard against including *redeposited* material, in which the loess and the coarser material have been brought down from higher ground. It may not in all cases be possible to decide whether there has been a redeposition. But the present writer feels

confident that he has seen not a few places where the basal portion of unmodified loess carries sand and coarser material. It is found that on the borders of the Mississippi Valley in southeastern Iowa, and also for some distance back from the stream, pebbles are of frequent occurrence in the lower portion of the silts, which there cap the Sangamon soil or rest upon the slightly eroded surface of the Illinoian till. Well-defined bedding planes also appear, especially in the basal portion of the silt, in which thin sand partings alternate with clay, giving an appearance similar to that found in the fine deposits of alluvium on the bottoms bordering the large streams. These pebbles and bedding planes have been found in Lee and Des Moines counties, Iowa, at an elevation of slightly more than 700 feet above tide, or fully 200 feet above the present level of the Mississippi River, and about 130 feet above the level of the lowest known deposits of loess in that region. The breadth of the glacial waters along the Mississippi Valley must have been 25 to 50 miles if the deposits just noted mark the highest level; possibly a still higher level was reached. Whether there was clear evidence of the spreading of glacial waters over the entire divide between the watersheds of the Mississippi and Illinois, can not be stated. But the known extent of the glacial waters seems adequate to have furnished material for mantling the higher portions of this divide by æolian agencies. Examinations in southern Illinois have brought to light the general prevalence of small pebbles in the silt which covers that district. There seems little question that from the base of the elevated ridge in southern Illinois northward, as far as these silts are exposed, outside the Wisconsin drift, the aqueous agencies have been influential and were probably the chief agencies of deposition.

To what extent the elevated ridge in southern Illinois was covered by glacial waters has not been determined. Possibly a portion of the silt which caps this ridge was deposited while the Illinoian ice rested upon its northern slope, though no positive evidence of such deposition has been noted.

The extent of the glacial waters on the borders of the Mississippi in northwestern Illinois and northeastern Iowa is also undetermined. Mr. Oscar Hershey has found water-bedded silt along the Pecatonica River and Yellow Creek valleys, in Stephenson County, Illinois, which he thinks immediately preceded the loess in deposition. This silt is confined to low levels along the valleys rising scarcely above the present water level. The full extent of water action in this basin has not been determined. It seems

probable that the loess on the immediate borders of the Pecatonica lobe is water-bedded, even at levels 800 feet or more above tide. Possibly this lobe held a body of water in the Pecatonica Basin at a level nearly as high as the bordering uplands (900 feet above tide).

The relation of the bluff loess to the upland loess is a question of prime importance. It has been commonly assumed that deposition was completed at nearly the same date on the uplands and on the valley borders, and that the difference in porosity is due to a greater strength of the current along the line of the main valleys. It is probably true that the main valleys were the line of strongest current during the deposition of the upland loess, and possibly the deposition of the bluff loess was completed at a date nearly as early as that of the water-laid deposits on the bordering uplands. There is thought, however, to be evidence pointing to a continuance of loess deposition along the main valleys after deposition had practically ceased on the uplands. The evidence referred to consists of an excessive filling by loess of the valley recesses and lower courses of tributaries, such as seem explainable as a result of transportation down the valley after the flooding of the uplands had ceased. Accumulations of this class are especially noticeable on the lower course of the Wabash and Ohio rivers, and they are found to some extent along the Illinois and Mississippi. Mr. H. F. Bain also reports that the same feature is noticeable along the borders of the Missouri River in western Iowa.[1] It is found that the blocking is most conspicuous on the east side of the valleys, a feature which suggests that wind action has been effective in causing the blocking of the mouths of tributaries, for the prevailing winds are from the west. Upon the retirement of the glacial waters to the limits of the main valleys or to their immediate borders the material available for transportation would be chiefly loess, and the loess would have had little opportunity to become leached. We may suppose, therefore, that a deposition of unleached loess continued until the glacial waters had retired completely and the streams were fed only by the rainfall of the region. This may have been maintained for some time after the disappearance of the Iowan ice sheet, though it appears not to have continued sufficiently long to have overlapped to any marked degree the valley excavation which followed the loess deposition.

As noted above, the fossils of the loess are confined largely to the

[1] Discussion at Twelfth Annual Meeting Iowa Acad. Sci., Dec., 1897.

immediate borders of the valleys, i. e., to the portion of the loess which may have been deposited after the retirement of the floods from the uplands. The most notable exceptions are their occurrence in the paha ridges and in the heavy loess bordering the lobes of Iowan ice in eastern Iowa and western Illinois. It seems difficult to refer the latter deposits to a much later date than the culmination of the glacial flood, though it is possible that the filling was continued along the immediate borders of the ice lobes to a time considerably later than the culminating stage of the flood and even to a time when vegetation had obtained a foothold on the neighboring silt-covered tracts. If the deposition of the portion of the loess containing fossils can be shown to have continued down to a time when the floods had retired to the limits of the main valleys, objections drawn from the character of the fossils against the aqueous deposition of loess on the bordering uplands would be fully met. It becomes, therefore, a matter of much importance to settle definitely the age of the fossil-bearing deposits with reference to the culminating stage of the glacial water.

Before leaving this subject a few remarks seem in place concerning the deposits of loess which are evidently æolian. The first æolian loess to attract the writer's attention, as such, is found along the east border of the Mississippi Valley opposite Burlington, Iowa. The loess there has accumulated in dunes which give it a relief of 25 to 75 feet above the neighboring uplands on the east. When viewed from the uplands it appears as a billowy ridge fringing the river bluff. This loess is found to be fossiliferous and calcareous, and were it not for its topography and for a slight admixture of sand recently drifted to it from the broad bottoms of the Mississippi River it would present no essential difference from the flat-surfaced portions of the loess along the borders of the river elsewhere. A similar relief of the loess on the brow of the bluff, above uplands to the east, has been since noted just below Alton, Illinois. It also occurs to a slight degree on the east border of the Mississippi above Burlington. It is now known that the general thickness of the loess on the east side of the Mississippi Valley, from the Driftless Area southward through the entire length of the State of Illinois, is markedly greater than on the west side of the valley in Iowa and Missouri, probably twice as great. A similar difference is found on the east and west sides of the Wabash Valley; on the Illinois the difference is not so marked. It is thought that this extra thickness of the loess on the

east borders of the valleys is the result of æolian agencies, for there seems no reason to suppose that the glacial waters, while overspreading the uplands on the borders of the valleys, would have deposited an excessive amount of sediment on the east side. Whether the æolian action is to be measured simply by the excess of the accumulation on the east bluff or should be made to include a portion on both bluffs of the stream is not as yet manifest. The west winds may have carried material from one valley across to its neighbor where valleys approach closely, as in the case of the Illinois and Mississippi, in Calhoun County, Illinois, where æolian loess appears to have covered the entire interval. The calcareousness of the æolian loess is significant and has an important bearing upon the determination of the source of supply and the date of deposition. The supply can hardly have been derived from the great western plains, where the material available for wind transportation is largely leached of its calcareous ingredients. It can not be referred to a much later date than the close of the Iowan stage of glaciation, since leaching would have rendered the surface portion of the silts noncalcareous. It can not be referred to a much earlier date, for it is separated from the Illinoian drift sheet by the Sangamon soil and weathered zone. As urged by Chamberlin, the æolian deposition appears closely connected with glacial and fluvial deposition.

CHAPTER VIII.

THE PEORIAN SOIL AND WEATHERED ZONE (TORONTO FORMATION?).

GENERAL STATEMENT.

The interval between the Iowan and Wisconsin stage of glaciation has been provisionally named Toronto by Chamberlin because of excellent exposures of interglacial fossiliferous beds along the Don Valley in Toronto, Ontario, which may prove to have this age.[1] Chamberlin remarks in connection with the introduction of this name that the grounds for this correlation are not very strong and that further investigation may show them to be erroneous. He further remarks that "whether the beds on the Don belong to the horizon suggested or not, it is certain that vegetal beds were formed in the interval of the retreat between the formation of the Iowan till and the formation of the Wisconsin till, and some of these less well developed and less known deposits must be looked to as a type of this interglacial horizon if the Toronto beds prove unavailable."

In view of the uncertainty attached to this correlation it seems advisable to employ for the present a substitutional name (Peorian) which is known to be applicable to the interval between the Iowan and the early Wisconsin. In case the correlation suggested by Chamberlin is demonstrated to be correct, the name Toronto has precedence.

SOIL AND PEAT BETWEEN THE IOWAN AND WISCONSIN DRIFT SHEETS.

Extensive deposits of muck and peat occur at the base of the Wisconsin drift in northern Illinois, notably in McHenry, Kane, Dekalb, Lasalle, and Bureau counties, which are in all probability immediately

[1] Classification of American glacial deposits, by T. C. Chamberlin: Jour. Geology, Vol. III, 1895, pp. 270–277.

underlain, in some cases at least, by Iowan drift. In central and eastern Illinois the soil is in places underlain by a fossiliferous silt, referred with some confidence to the Iowan loess. In eastern Illinois, as noted above, the Iowan till may be present. This soil horizon, together with lower soil horizons, was discussed by the writer in a paper presented at the Cleveland meeting of the American Association for the Advancement of Science.[1] At that time the separation of the Iowan sheet from the Illinoian had not been made and all the soils were referred to a single horizon. The later developments have led the writer to separate the soils found at or slightly below the base of the Wisconsin drift into two classes, one class being thrown into the Sangamon stage, while the other is thrown into the stage under discussion. It is not possible in all cases to decide to which class a buried soil should be referred, for in some cases its existence is known only through well records. Such separations as have been made may be found in the discussion of the wells of Illinois, in the latter part of this report, and in the discussion of the Iowan till above.

In selecting a name for the horizon the ideal locality would be one in which the earliest sheet of Wisconsin till overlies the Iowan till. In the vicinity of Marengo, in McHenry County, a black muck has been found at the base of the Wisconsin drift, and it apparently rests on Iowan till. This might be taken as a type locality were it not that the Wisconsin drift at that point may not include the Shelbyville or earliest Wisconsin sheet of till. The same objection may be urged against buried soils found in Kane, Dekalb, Lasalle, and Bureau counties, for in all these counties the outer Wisconsin ridge appears to be the Bloomington moraine, and the limits of the Shelbyville may be to the east of this ridge. It has seemed advisable, therefore, in the selection of a type locality to pass to central Illinois, where the Shelbyville sheet extends beyond the later sheets of Wisconsin drift. This unfortunately carries us beyond the Iowan till, but the loess whose deposition seems to be connected closely with the Iowan glaciation is there well developed. The interval between the loess and Shelbyville till sheet probably marks, as well, the time between the culmination of the Iowan and Wisconsin glaciations, as if taken where the Shelbyville sheet overlies Iowan till.

[1] For abstract of paper, see Proc. Am. Assoc. Adv. Sci., Thirty-seventh Meeting, 1888, pp. 183, 184.

LEACHED LOESS BENEATH THE WISCONSIN DRIFT.

The loess has been traced back in valley exposures several miles beneath the Shelbyville till sheet in northern Tazewell County, Illinois, and beneath the combined Shelbyville and Bloomington sheets in Woodford and Bureau counties. Farther south it has been recognized in well sections in southern Tazewell, northeastern Logan, western Dewitt, southern Macon, and western Sullivan counties, Illinois. The phase known as white clay has been traced several miles up the Kaskaskia and Embarras valleys, in Shelby and Coles counties, beneath the Shelbyville till sheet.

Of the several exposures in which the loess appears below the Shelbyville drift, those east of Peoria, in northern Tazewell County, are the best displayed. Decisive evidence is also found at these exposures of an interval of some length between the deposition of the loess and the deposition of the overlying Shelbyville till sheet. In view of these conditions in the vicinity of the city of Peoria, it has seemed appropriate to apply the name Peorian to the interval between the Iowan loess and the Shelbyville till sheet.

In exposures along the Toledo, Peoria and Western Railway east of Peoria, and also on the east bluff of the Illinois opposite that city, the Shelbyville sheet is underlain by a bed of fossiliferous loess, similar to that found on the surface of the Illinoian outside the limits of the Shelbyville drift sheet, both in texture and in age. The loess is 8 to 12 feet in thickness, or about the same as on the uplands outside the Shelbyville sheet. It occurs at a corresponding elevation of about 200 feet above the Illinois River. Beneath it there is exposed fully 100 feet of the older or Illinoian drift sheet. In places the upper part of the loess to a depth of 2 or 3 feet presents a darker brown color than the lower portion and is partially leached of its calcareous ingredients. In one place, about 3 miles west of Washington, a thin soil carrying fragments of wood is exposed in the bluff of Farm Creek at the top of the loess. These exposures east of Peoria were thought to afford excellent opportunities for a comparison of the Peorian and Sangamon weathered zones, and were consequently visited in May, 1898, by a party of geologists in company with the writer, including Profs. T. C. Chamberlin, Samuel Calvin, J. A. Udden, Dr. S. W. Beyer, and Dr. H. F. Bain. It seemed to all present that the Sangamon weathered zone calls for more time in its formation than appears to have been required in

the development of the Peorian zone as there displayed. It is possible, however, that other lines of evidence next to be considered may call for a period of greater length between the Iowan and Wisconsin stages of glaciation than these exposures of the Peorian weathered zone seem to require.

IOWAN OUTLINE COMPARED WITH SUCCEEDING AND PRECEDING GLACIATIONS.

Evidence of an interval between the Iowan and early Wisconsin glaciations is found in the great dissimilarity in the outline of the two ice sheets. The outline is more out of harmony, both with the early Wisconsin and the Illinoian, than the outline of these sheets with each other. The great extension toward the south border of the Driftless Area, both in the Iowa and Illinois lobes of Iowan ice, is singularly out of harmony with both succeeding and preceding glaciations. The shifting of lobes involved in the change from the Iowan to the early Wisconsin can scarcely be assumed to have occurred in a brief interval. The moraine-forming habit of the Wisconsin and absence of distinct morainic belts in the Iowan also implies a change in glacial conditions that can hardly have taken place suddenly.

CHANGE IN ATTITUDE OF THE LAND.

Evidence of an interval between the deposition of the Iowan loess and associated silts, and that of the Shelbyville till, is found in a change in the attitude of the land, which resulted in a marked deepening of the valleys. There appears to have been a greater depth of excavation during the Peorian stage than during the Sangamon. The breadth of excavation, however, amounted to but a fraction of that in the Sangamon stage.

LENGTH OF THE PEORIAN STAGE.

The amount of change in altitude can as yet scarcely be even conjectured, much less demonstrated, but its effects on the drainage are such as to support the view that it denotes a time interval of considerable length, a view which is also supported by the work accomplished in deepening the valleys. Comparing the work with substages of the Wisconsin it appears that the interval may not greatly exceed that between the Shelbyville and Bloomington ice advances. The Shelbyville sheet had become channeled

by streams prior to the Bloomington substage of glaciation to nearly as marked a degree as the channeling below the level of the loess effected in the Peorian stage of deglaciation. There was also a marked increase in the stream gradients, the Bloomington drift sheet being accompanied by a much more vigorous gravel outwash than that which accompanies the Shelbyville sheet. In the writer's opinion it is questionable if the interval between the Iowan and early Wisconsin invasions covers more than a small fraction of the time occupied by those between the Iowan and Illinoian and between the Illinoian and Kansan. The union of the several lines of evidence just cited would seem to support the view that it is longer than the interglacial substages of the Wisconsin. The view of a brief interval between the Iowan and Wisconsin, however, meets a strong objection in the supposed attendant deposits at Toronto.

THE TORONTO FORMATION.

Turning to the Toronto formation it is found that a fossiliferous silt occupying a horizon between bowldery glacial clays has a fauna and flora which denote a climate fully as mild as that which at present characterizes that region.[1] In discussing this formation Dr. A. P. Coleman remarks that unless the Labrador gathering ground is shown to have stood much higher than at present, it can scarcely be supposed that a widespread sheet of ice was maintained there while oaks and maples and pawpaws flourished on the land and Mississippi unios in the waters, within 400 to 500 miles to the southwest. In the absence of any evidence of such uplift, he concludes that the ice fields were completely melted during this interglacial epoch.

The extent of deglaciation suggested by these beds, so far as space is concerned, can scarcely be supposed to have been exceeded either by the Sangamon or the Yarmouth stage of deglaciation. The Toronto beds constitute probably the most decisive evidence yet brought forward in support of an extensive deglaciation within the Glacial period. The time involved may reasonably be supposed to cover a portion of the Glacial period by no means small. Its rank should be as high as that of any of the interglacial

[1] See descriptions by Dr. A. P. Coleman and Prof. D. P. Penhallow: Am. Geologist, Feb., 1894, Vol. XIII, pp. 85–95. See also additional interpretation by Dr. Coleman: Jour. Geol., Vol. III, pp. 274, 622–645. For description of fossiliferous beds at Scarborough Heights and other localities near Toronto, by Dr. George J. Hinde, see Jour. Canadian Inst., April, 1877.

stages, even if less prolonged than some of the earlier stages of deglaciation. Should it be proved to represent the interval between the Iowan and Wisconsin deposits, as now seems probable, the evidence above cited, from the peripheral portion, may aid in determining its length, namely, the leaching and erosion of the Peorian stage. As yet the fauna and flora buried beneath the peripheral portion of the Wisconsin drift have received little or no attention. Possibly by the aid of this line of study the question of correlation may be settled.

CHAPTER IX.

THE EARLY WISCONSIN DRIFT SHEETS.

GENERAL STATEMENT.

The northeastern fourth of Illinois and adjacent portions of Indiana are covered by a sheet of drift somewhat fresher than the Iowan, which has its terminus in the Shelbyville moraine, but which embraces several morainic systems of considerable prominence that lie between the Shelbyville moraine and the border of Lake Michigan. The term "early Wisconsin" is restricted to the moraines which lie outside the bulky moraine that encircles the head of the lake and which was discussed by Chamberlin in the Third Annual Report as the terminal moraine of the second Glacial epoch. In that report Chamberlin referred briefly to the occurrence of morainic lines outside the moraine which formed the theme of his paper, and recognized the general freshness of the drift and unsculptured contour of its surface compared with that of the districts nearer the glacial boundary and outside the limits of the Wisconsin drift.[1] The group here recognized as the early Wisconsin forms a somewhat concentric series, as may be seen by reference to the glacial map (Pl. VI). The moraines included in the late Wisconsin are not concentric with the earlier group. On the contrary, they cross the earlier moraines in western Indiana and override the greater portion of the district which the early Wisconsin occupies. In Illinois the early Wisconsin is well exposed outside the late Wisconsin series, probably better than in any other part of the glaciated district. If our interpretations are correct, it is only represented by a single moraine in eastern Indiana and southwestern Ohio, while farther east it is entirely concealed by the later deposits or so merged with them as to have escaped recognition.

[1] Third Ann. Rept. U. S. Geol. Survey (for 1881–82), 1883, p. 331.

SECTION I. SHELBYVILLE MORAINIC SYSTEM.

EXTENT OF THE SHELBYVILLE SHEET.

The outer border of the Shelbyville sheet is found in the Shelbyville moraine, an outline of whose position is given below. This moraine is but the thickened edge of a drift sheet, which not only covers the territory occupied by the moraine and the plain between it and the next succeeding morainic belt, but apparently extends many miles to the north beneath the later moraines, for the fresh drift which characterizes this moraine is found to extend below the base of the later moraines. As shown by Chamberlin in his discussion of the drift of North America in the last edition of Geikie's Great Ice Age, there is an imbricate arrangement of drift sheets by which the later to some extent overlap the earlier. This is found to be true of the several divisions of the Wisconsin sheet as well as of the main divisions of the drift, known as the Wisconsin, Iowan, Illinoian, etc., though the extent of overlapping is much less than in the main sheets. As already remarked, the several moraines appear to have been formed by readvances of the ice of more or less consequence rather than by simple halts during its recession.

SHELBYVILLE MORAINE.

The oldest moraine of the Wisconsin drift, so far as recognized, is one exposed to view in central and eastern Illinois and western Indiana, but which is overridden by later moraines in districts farther north and east. This has for some years been known as the Shelbyville moraine, the name being derived from a city in central Illinois which is situated on the extreme southwest point of the morainic loop. If we may judge from the amount of erosion and weathering, it is somewhat older than the Altamont moraine of the "Minnesota Valley glacier"[1] as well as the outer Wisconsin moraine in the eastern United States.

The thickened edge of this drift sheet has usually a breadth of several miles, and merges gradually into the plain on the inner border, so that it becomes difficult to limit the extent of the moraine. The crest usually is found within 1 or 2 miles of the outer border, and is, as a rule, much nearer the outer than the inner border of the thickened portion of the drift sheet.

[1] See Third Ann. Rept. U. S. Geol. Survey, p. 388.

DISTRIBUTION.

From Shelbyville the moraine bears eastward to the Indiana line, and deviates but slightly from a straight course. There is a slight lobation at the Embarras Valley which carries the moraine perhaps 5 miles south of a direct line. There is also a slight reentrant angle south of Paris, Illinois, carrying it 2 or 3 miles north of a direct line. The following villages are situated near the south border of the moraine: Shelbyville, Windsor, Paradise, Trilla, Janesville, Diona, Westfield, Swango, and Nevins. The cities of Mattoon, Charleston, and Paris are situated near the inner border of the moraine.

The moraine enters Indiana immediately west of the city of Terre Haute and bears northward along the west side of the Wabash Valley to northern Vigo County, where it crosses to the east side of the river, but continues northward into Parke County along the narrow uplands between the Wabash River and Big Raccoon Creek as far as the mouth of the creek near Montezuma. Here it turns abruptly to the east and maintains an eastward course across Parke County and nearly to Bainbridge in Putnam County, where it turns southward for a few miles, crossing Walnut Creek near the city of Greencastle. From Greencastle the course is eastward past Mount Meridian, Little Point, and Monrovia to the vicinity of Mooresville, in northern Morgan County. From Mooresville the course is southward through eastern Morgan County, but the moraine is so feebly developed that the position is difficult to outline. The Shelbyville drift sheet apparently extends into southeastern Morgan and southwestern Johnson counties, its limits in these counties being a few miles outside a later moraine. But in southern Johnson County the later moraine extends to the extreme limits of the Shelbyville sheet. A moraine thought to be the Shelbyville reappears a few miles southeast of Columbus, Indiana, and has been traced from that point eastward into southern Ohio. But that portion of the moraine lies outside the limits of the district covered by the present report.

From Shelbyville, Illinois, the moraine is found to take a northward course, passing a few miles west of the cities of Decatur and Clinton, the villages of Macon, Harristown, Warrensburg, Hallsville, and Waynesville being situated on it. From Waynesville the course is northwestward past Atlanta to Delavan. The moraine here takes a northward course and

crosses the Illinois River immediately above the city of Peoria. In Peoria County it passes immediately west of Alta, Dunlap, and Edelstein, leaving the county near the corners of Stark and Marshall counties. It there becomes merged with a later moraine (the Bloomington), and is apparently covered by the later sheet of drift throughout northern Illinois.

RELIEF.

Throughout much of its course in Illinois this moraine presents a bold relief when viewed from the outer-border district. It is seldom less than 60 feet, and in places reaches fully 150 feet, above the outer-border plain. It ordinarily presents a relief of 75 to 100 feet. The greatest relief (150 feet) is found in Edgar County, between Paris and Kansas. In Indiana the relief is much less than in the Illinois portion of the moraine. Along the Wabash Valley it amounts to scarcely 50 feet, while east from the Wabash it is usually but 20 to 40 feet.

When viewed from the inner border the moraine presents a perceptible relief only along a small portion of its course. It usually merges into the inner-border plain so gradually that the border can scarcely be mapped. The relief on the inner-border plain is more pronounced for a few miles north and south of the Illinois River than elsewhere in its course, but even there it scarcely exceeds 75 feet.

RANGE IN ALTITUDE.

Occupying as it does a comparatively smooth country, the moraine presents but a small range in altitude. In the Indiana portion the highest points crossed by it are near Bainbridge, and have an elevation of about 950 feet above tide. At White River Valley it but little exceeds 600 feet, and at the Wabash Valley it falls slightly below 600 feet. At the Illinois-Indiana line the highest points on the moraine are scarcely 675 feet, but at the Kansas geodetic station, only about 20 miles west from the State line, a point on the moraine has a measured altitude of 839 feet above tide. Westward from this geodetic station the altitude soon declines to 775 feet, and throughout much of the interval between Kansas and Shelbyville it stands 750 to 775 feet above tide. At the bluffs of the Embarras River, however, it scarcely exceeds 700 feet, and at the Kaskaskia bluffs in Shelbyville it is but 675 to 700 feet. Throughout much of the distance from Shelbyville to the Sangamon River near Decatur the altitude is little more

than 700 feet, while at the river bluff it is about 650 feet. Between the Sangamon River and Peoria the highest points along the crest are about 800 feet, and the crest seldom falls below 700 feet. Near the east bluff of the Illinois, at Groveland, the altitude is 785 feet, or more than 350 feet above the Illinois River; but in the northeast part of Peoria the moraine appears on the west bluff of the river at an altitude scarcely 200 feet above the stream. Passing northward the moraine soon rises to a height of 800 feet and stands near this elevation throughout its course in northern Peoria County and in eastern Stark County to where it is overridden by the Bloomington moraine.

SURFACE CONTOURS.

Although this moraine constitutes the margin of a thick sheet of drift and has usually considerable relief on its outer border, it presents in general a comparatively smooth surface, sharp knobs being developed only at a few points, and swells or undulations of the surface being of a gentle, unobtrusive type. In places it has no more undulation than has the plain north of it. Were one not aware of the great relief above the outer-border district and certain that this relief is due entirely to the presence here of a sheet of drift not found in the outer-border district, one might well question the propriety of considering this a morainic belt. But these criteria place beyond question the termination of the ice invasion along this line, and no better term than moraine seems applicable to such a thickened drift terminus. In this connection it may be remarked that where there is an attenuated drift border at the margin of the glaciated district, the term glacial boundary seems preferable to moraine, but in the case of the margin of a later drift sheet which lies back some distance from the glacial boundary it would seem necessary to substitute some definition or explanatory term. In case the later drift sheet under discussion should have an attenuated border the term moraine scarcely seems applicable, and it would be preferable to substitute the term Wisconsin boundary, but if the drift sheets have a thick edge and bold relief, as is generally the case, the term moraine seems applicable even though no sharp morainic contours are present. As it is, however, a portion of the margin of this drift sheet presents characteristic morainic features, and these features pass, by insensible gradations, into the more nearly plane portions of the border. To set forth fully the topography of this border a somewhat detailed description is necessary.

At very few points between Shelbyville and Peoria are there knolls or ridges worthy of note, almost the entire surface, both along the crest and the outer face of the moraine as well as its inner slope, being nearly plane. The outer face occupies a width of a mile or more. It shows slight irregularities of outline in the form of projecting points and bay-like recessions, which cause a deviation of a half mile to a mile or more from a direct line. North from the Sangamon River the surface is somewhat more undulatory than in the interval between the Kaskaskia and Sangamon rivers, but the drift swells are usually but 10 to 20 feet in height. The sharpest drift knoll noted is about 2 miles north of Decatur and is scarcely 50 feet in height. Knolls and ridges west of Forsythe are 30 feet or more in height. In southwestern McLean and southeastern Tazewell counties there are several sharply outlined small ridges lying back 5 or 6 miles from the outer border of the drift sheet and trending parallel with it. They rise 20 or 30 feet, and in places 50 feet or more, above the bordering plains. In the portion of the plain between the Mackinaw and Illinois rivers there is, in addition to the relief of 50 or 60 feet on the inner border, an undulatory surface with swells 10 to 25 feet in height. The portion north from Peoria has only gentle swells 10 to 15 feet in height, but with these swells there are occasional basins 3 to 6 feet in depth, which add somewhat to the expression of the moraine. The moraine here is narrowed to a belt only 2 miles or so in width, and, as the relief is 50 or 60 feet, the expression is more pronounced than throughout the greater part of the border of this drift sheet.

Eastward from Shelbyville the moraine is found to have very little expression in eastern Shelby County, the surface being nearly as smooth as that of the plain on the north. Upon approaching the Embarras Valley in Coles County, the moraine is found to be separable into at least three distinct ridges with east-west trend. The ridges each have a nearly plane surface, with smooth slopes, but present a relief of 30 to 50 feet above the intervening sags. On the east side of the Embarras River, near the line of Coles and Cumberland counties, a few knolls, 10 to 25 feet in height, appear on the outer face of the outer ridge. In Edgar County the moraine consist of two more or less distinct ridges. They are more distinct in the southwestern than in the southeastern part of the county. In the vicinity of Grand View and westward into Coles County the ridges stand about 50 feet above the sag which separates them. The south ridge is forest

covered, while the north ridge was a prairie at the settlement of the county. Each ridge is characterized by low knolls and shallow basins. Occasionally the knolls reach a height of 30 feet, but they are usually only 10 or 15 feet in height. In the vicinity of Nevins a narrow outer ridge appears for a few miles, which has sharp knolls 30 feet or more in height.

Upon passing into Indiana the moraine loses the definite ridging which it displays in Coles and Edgar counties, Illinois, and is represented in northwestern Vigo County by a sheet of drift carrying only occasional knolls. In a few cases the knolls reach a height of nearly 50 feet. The portion of the moraine lying between the Wabash River and Big Raccoon Creek is gently undulatory and more definitely ridged than that in northwestern Vigo County. From the Wabash Valley eastward to Greencastle the moraine has generally a gently undulating surface, with few knolls exceeding 20 feet in height. From Greencastle eastward the drift sheet seems to be represented in places only by small knolls and ridges, standing but 15 to 25 feet above the outer border. Among these knolls and ridges are plains of considerable extent in which the Shelbyville sheet seems to be very attenuated. It becomes difficult to trace the border by the topography, and it has been found necessary to rely mainly upon the structure of the drift deposits. As indicated below, the removal of the loess and the replacement by a bowldery drift gives the line at which this invasion terminated sufficient definiteness to admit of mapping.

STRUCTURE AND THICKNESS OF THE DRIFT.

With the exception of the surface portion, which is variable in structure because of local deposits of silt, sand, or gravel, the drift in this moraine is, in the main, a typical till. For a depth of 8 to 12 feet, and occasionally for 20 or 25 feet, from the surface it presents a brownish-yellow color, which changes below to a grayish yellow and yellowish gray and finally to a blue gray. The blue-gray till constitutes the main body of the drift sheet. It as about as thick as the measure of the relief of the drift sheet above the outer-border plain, which in Illinois, as above noted, ranges from 60 to about 150 feet, and in Indiana seldom exceeds 40 feet. In places a bed of sand or gravel is found at the junction of the yellow and blue tills, suggesting that they may represent distinct deposits, but there are many more places exposed to view where the yellow till grades downward into the blue till. Furthermore, there are included within both the

yellow and the blue till local beds of sand or gravel similar to those at their junction. It seems on the whole probable that the two clays constitute but a single deposit, and that the color distinction has been largely acquired since deposition. This view seems supported by the fact that the deposits are similar in structure, even in the number of striated stones and in the calcareous rock flour which they contain. The surface portion of the yellow clay to a depth of 4 to 6 feet is more highly oxidized and shows greater discoloration than the lower portion, and contains but little calcareous material, but these features seem to be due in the main to weathering subsequent to deposition and not to original differences.

Surface bowlders are irregularly distributed over the moraine. They are nowhere rare, and occasionally become so numerous as to be troublesome in cultivating the land. In eastern Illinois they are most conspicuous in the southwestern part of Edgar County. The bowlders consist almost entirely of Canadian rocks, and few of them exhibit striæ or glacial planing. Some are sharply angular, a feature which indicates that but slight surface change has been produced since they were deposited. This being the case the absence of striæ is due not so much to weathering and removal after striation had occurred as to an escape from striating agencies. It is thought that their transportation may have been at a level considerably above the base of the ice sheet.[1]

The portion of the Shelbyville moraine north of Shelbyville carries a larger amount of surface silt than the portion east of that city. Not only the moraine but the district to the east, for a distance of perhaps 20 miles, has a coating of silt so thick that bowlders are completely concealed, for it not infrequently reaches a depth of 5 or 6 feet. On the portion east from Shelbyville the silt is usually but 1 to 2 feet in depth, so that bowlders are frequently seen at the surface. In the vicinity of the Wabash Valley, however, the thickness is 4 to 6 feet. The silt is usually of a brownish-yellow color, much like that of the oxidized till underneath it, though slightly paler than the till. Where thickest it is somewhat calcareous in the lower portion and carries small molluscan shells of land and water species, similar to those found in the Iowan loess. The silt, however, is usually leached to a depth of 3 or 4 feet. This silt appears to have been deposited very soon

[1] Comp. Chamberlin, Jour. Geol., Vol. I, pp. 47–60.

after the till which underlies it, for the latter is not leached except where the surface leaching has extended below the base of the silt. As to the origin of this silt, it may be remarked that the calcareousness seems to indicate derivation from the Shelbyville drift rather than from the Iowan loess. The loess of the outlying districts is so thoroughly leached to a depth of several feet that it can hardly be the source of supply. Exposures were found near Princeville, in the district west of the Shelbyville moraine, where a fresh calcareous silt such as caps the moraine overlies the Iowan loess. Acid tests also indicate that the surface silt is more calcareous than the underlying loess.

Beneath this drift sheet, at about the level of the district outside the moraine, the earlier or Illinoian drift is struck. The junction between the earlier and later drift is often marked by a soil or other equally clear indication of an old land surface. The passage from one drift to the other is readily recognized by well drillers because of the difference in hardness, the earlier drift being partially cemented and much more difficult to penetrate than the overlying later drift sheet. As noted below, exposures of the earlier drift were found in the Illinois, Kaskaskia, and Embarras valleys in Illinois. The majority of the streams in Illinois fail to reach the level of the earlier drift in their passage through the moraine. Those of Indiana more often have cut into the older drift.

The thickness of the Shelbyville drift in the Illinois portion of the moraine is much greater than that of the underlying older drift, the average thickness of the former being nearly, if not quite, 100 feet, while the latter attains that thickness only in the valleys or lowland tracts which it filled, and has in this region a general thickness scarcely half as great as that of the Shelbyville drift sheet. Our knowledge of the thickness of the Shelbyville sheet is based mainly upon the relief of the moraine, and the estimate of the thickness of the older drift is based upon its thickness in districts outside the moraine, rather than upon borings within the limits of the moraine, there being few wells which have reached its bottom. There are, however, a sufficient number of records of deep wells along the moraine, or in the districts north of it, to furnish a fair knowledge of this earlier drift sheet.

As may be inferred from previous statements, the Shelbyville drift sheet is much thinner in the Indiana than in the Illinois portion of the

moraine. Several of the valleys have been cut through it to the underlying older drift, and ravines heading in the newer drift very frequently reach a level below its base before emerging into the older drift district. Wells also not infrequently pass into the older drift before obtaining a supply of water. It is estimated that the thickness of the Shelbyville drift sheet along the course of the moraine in western Indiana averages only 25 or 30 feet and rarely exceeds 40 feet. On the plain north of the moraine it apparently falls below 20 feet. Before the deposition of this sheet shallow interglacial valleys appear to have been opened and where they were filled the thickness of the Shelbyville drift is in some places perceptibly greater than on the neighboring uplands, so that valleys 40 feet or more in depth have in some cases failed to cut down to its bottom. The older drift in western Indiana fills the preglacial valleys to considerable depth, often exceeding 100 feet. But on uplands its thickness is much less and apparently averages but little greater than the Shelbyville sheet.

In the latter part of this report, and in Water-Supply and Irrigation Paper No. 26, on Wells of Southern Indiana, numerous sections will be found which set forth the structure of the drift along the line of this moraine. It is necessary, therefore, to call attention to but a few of the more important sections in this place. These are presented in order from the east westward.

A well showing a large amount of drift was sunk by L. B. Humphries in the west part of the village of Rockville. For about 40 feet the till was found to be of fresh color and easy to penetrate. This probably marks the depth of the Shelbyville drift sheet, for a hard till was then entered, which continued to a depth of 168 feet. Some wells in the village of Rockville have passed through a black soil at the base of the Shelbyville sheet. In some cases where the ground is slightly lower than at the well just noted, it is found at a depth of but 17 to 20 feet. With the soil there is usually considerable wood. In western Parke County, in the portion of the moraine between Big Raccoon Creek and the Wabash River, wells at several farm houses have passed through a black soil at the base of the Shelbyville drift sheet. On a tributary of Big Raccoon Creek, on the farm of E. D. Wicks, in sec. 6, T. 14, R. 8 W., an exposure of soil below till is found at a lower elevation than that struck in the neighboring wells, there being fully 50 feet of till above the soil, while in the wells there is usually but 20 or 25 feet.

It is probable that the lower elevation of the soil is due to its being formed in an interglacial valley, though possibly it marks a lower horizon than the base of the Shelbyville sheet. The soil contains much wood and mats of decayed leaves. A spring issues from this soil bed which carries a small amount of inflammable gas.

An artesian well drilled by the Roman Catholic Sisters of Providence at St. Mary's penetrates 100 feet of drift, of which the upper 75 feet is till and the remainder clay and quicksand. The full section of the well to a depth of 1,955 feet is published in the Twenty-first Annual Report of the Indiana Geological Survey (p. 524).

At Sanford, on the State line of Indiana and Illinois, the drift is found to have a thickness of 147 feet. It is thought that only the upper 25 feet belongs in the Shelbyville drift sheet. The following record, except the parenthetical portions, which are added by the writer, appears in the Indiana Geological Report for 1875 (p. 94):

Section of drift in a well at Sanford, Illinois.

	Ft.	in.
Surface (yellow till)	15	0
Sand	6	0
Sand and clay	4	0
Hardpan (Illinoian?)	66	0
Brown clay	10	3
Blue clay	8	4
Sand	0	4
Blue clay	37	6
Total	147	5

At Paris the waterworks well was sunk to a depth of 60 feet, of which the upper 50 feet is till and the remainder sand and gravel. At the base of the till considerable wood is found. It seems probable that the well extends to the base of the Shelbyville drift sheet.

At Charleston the distance to rock ranges from 30 feet or less to at least 127 feet, a well in the north part of the city having reached no rock at that depth. Along the Embarras Valley, south of Charleston, several exposures were found in which the Illinoian drift, with the capping of white clay, appears below the till of the Shelbyville sheet. The northernmost exposure noted is a few rods west of the iron bridge, 3 miles southeast of Charleston. At that point the Shelbyville drift sheet extends to within about 20 feet of the river level. Near the south line of Coles County the older (Illinoian) drift is found to reach an elevation 50 or 60 feet above the

river bed. Exposures of the older drift with the capping of white clay were also noted in northern Cumberland County, along western tributaries of the Embarras River.

Records of several wells in the vicinity of Lerna were obtained in which no rock was entered at a depth of 100 feet, and one boring reached a depth of 132 feet without striking rock. A large part of the drift appears to belong to the Shelbyville sheet.

At Mattoon a coal shaft has the following section, as reported in the Geology of Illinois, which suggests that the Shelbyville sheet there may be but a few feet in depth:

Section of drift in a coal shaft at Mattoon, Illinois.

	Feet.
Surface soil	5
Yellow clay	8
Sand (blue)	3
Hardpan (Illinoian?)	35
Sand and gravel	17
Blue clay and gravel	38
Total drift	106

At Windsor the town well has a depth of 127 feet and does not reach rock. It is reported that a soft blue till sets in within 10 feet of the surface, and extends to a depth of 90 feet. Here a hard, stony, brown clay, probably Illinoian, was entered, which changed within a few feet to sandy water-bearing clay, and the amount of water gradually increased until a good supply was obtained at a depth of 127 feet. Several prospect borings for water have been made in Windsor by Jerry Linnville, in one of which a black muck was found at about 100 feet. This was probably at the base of the Shelbyville drift sheet, and at the same horizon as the brown clay struck at 90 feet in the town well. A slight amount of gas was found near the level of this muck. It appears to have been at a level slightly lower than the muck, and hence is less likely to have been derived from it than if found at a higher level. Possibly its source is from underlying shale. It is thought that one boring reached the shale at 170 feet.

Along the Kaskaskia Valley in the vicinity of Shelbyville there are exposures of the Illinoian drift, capped by a white clay similar to the surface white clay of the outer-border district, but here overlain by about 20 feet of till of the Shelbyville sheet One exposure is found within the

city of Shelbyville, in the street grading leading from the court-house eastward to the wagon bridge. Another is found about a half mile east of the wagon bridge, where a road leads off to the south. At this place there is a well-defined soil (Sangamon) between the white clay and the underlying Illinoian drift. The contrast in hardness of the drift sheets is very striking, the drift of the Shelbyville sheet being fresh and easily penetrated by spade or trowel, while the older drift is partially cemented and its brownish-blue till is traversed by veins of deep-brown color not seen in the blue till of the Shelbyville sheet. No better place to study the two drift sheets has been found than is afforded in the vicinity of this city. There are exposed in vertical section numerous cuttings and exposures of both drift sheets, including also the buried soil and the buried white clay which caps the older drift. The topographic features of the two sheets are also well displayed. The contrast is not exceptionally striking here, but the opportunity for making comparisons is exceptionally good.

In the vicinity of Macon, the first town of importance situated on the moraine north from Shelbyville, an inexhaustible supply of water is found in sand and gravel near the base of the Shelbyville drift sheet at a depth of 100 to 120 feet. The quantity of water is so great as to have prevented the sinking of a coal shaft at this town. Gas in considerable amount has been encountered in wells between Macon and Decatur, and also over a considerable area east of Macon. The gas is found in beds of sand and gravel, which are in some instances located in the lower part of the Shelbyville drift sheet, but more often in beds associated with the underlying Illinoian drift. In some cases the gas is found in the shale which immediately underlies the drift. Well drillers can readily distinguish the Shelbyville drift sheet from the underlying Illinoian drift, and they report that it is not uncommon to find a bed of white clay, such as caps the district outside the Shelbyville sheet, at a corresponding elevation under the Shelbyville sheet. The thickness of the Shelbyville sheet ranges from 60 to 120 feet or more, and there is usually so little sand and gravel associated with it that the tubular wells are sunk into the underlying older drift.

At Decatur the records of a coal shaft and air shaft[1] show marked contrasts in the drift sections. The distance between the shafts is about one-

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[1] Published in the Geology of Illinois, Vol. VIII, pp. 15 and 48.

half mile. The following is the section of the air shaft as furnished by Charles Hansel, of Decatur:

Section of drift in an air shaft at Decatur, Illinois.

	Feet.
Soil and loamy clay	25
Sand and water, flow of 400 gallons per minute	30
Blue clay	4
Driftwood and soil	2
Green sand	4
Gray sand	6
Hard blue clay	9
Sand and gravel, fine strata	37
Hardpan	23
Total drift	140

The bed of driftwood and soil was struck at about the level of the surface of the older drift sheet outside the moraine; it may be either Peorian or Sangamon. In the coal shaft two soils are reported, of which the lower one appears to be in the midst of the older drift; at least it is placed below a gravelly hardpan, such as is commonly reported when the older drift is struck. The following is the section as published in the Geology of Illinois:

Section of drift in a coal shaft at Decatur, Illinois.

	Ft.	in.
Soil and clay	31	0
Sand with two clay bands	11	0
Quicksand	2	6
Tough clay	4	0
Black soil	2	6
Sand	2	0
Clay	3	0
Greenish sand	6	0
Gravelly hardpan	11	0
Black soil	2	0
Quicksand	4	0
Gravelly clay	24	0
Quicksand	6	6
Total drift	109	6

Many wells in the vicinity of Decatur are sunk to a depth of about 80 feet before obtaining a strong supply of water. The till is apparently a nearly unbroken sheet. On the moraine west of Decatur, in the vicinity of Harristown, wells are often sunk through blue till to a depth of 100 or 125 feet. It is thought that they obtain their supply of water at or near the base of the Shelbyville sheet. North from Decatur, in the vicinity of Maroa, about 60 feet of blue till is penetrated before water-bearing sand or

gravel is reached. The waterworks wells at Maroa have a depth of about 100 feet and terminate in gravel.

At Clinton the drift is found to have the remarkable thickness of 352 feet, making the altitude of the rock surface there but 380 feet above tide. In the record published by Worthen[1] twenty-seven changes in drift structure are reported. The lower 140 feet of the drift is entirely sand and gravel, while in the remaining 212 feet there are thin beds of sand and gravel whose combined thickness amounts to but 47 feet, the bulk of the deposit being of clayey constitution. Another boring about one-half mile north of the one recorded is reported to have penetrated only 270 feet of drift. In the vicinity of Hallsville, 6 miles west of Clinton, several gas wells have been obtained in beds of gravel below blue till at depths ranging from 96 feet to about 140 feet. Some of these wells furnished a sufficient amount of gas to supply fuel for one or more stoves, but at last accounts (1897) the supply was decreasing.

The section[1] of one of these gas wells on James Barnett's farm shows an interesting series of drift sheets separated by buried soils, as follows:

Section of a gas well in drift near Clinton, Illinois.

	Feet.
1. Soil and yellow clay	15
2. Blue clay	30
3. Black soil, with wood	3
4. Drab clay	8
5. Black mold and driftwood	8
6. Drab-colored clay	20
7. Driftwood (log?)	2
8. Drab-colored clay	21
9. Hardpan	12
10. Drab-colored clay	¼
11. Greenish clay	10
12. Sand, etc	5
Total	137

In this section it is probable that only 1 and 2 are to be included in the Shelbyville drift. Number 3 appears to be the Peorian soil which caps the loess in the region outside the moraine, while 4 probably represents the loess and 5 the Sangamon soil between the loess and Illinoian drift.

In the vicinity of Atlanta the drift has a known thickness of over 200 feet. Records of several wells were obtained which range from 125 to 210

[1] Geology of Illinois, Vol. VIII, p. 34.

[1] Published in the Geology of Illinois, Vol. VIII, pp. 58, 59; also p. 13.

feet in depth, and none of them reached the rock. They penetrate about 100 feet of soft till of blue color, probably referable to the Shelbyville sheet, beneath which a harder, brownish-blue till is entered, which seems referable to the Illinoian drift. The village of Atlanta obtains its waterworks supply from two 8-inch wells 151 feet in depth. The following detailed record of the drift beds penetrated was furnished by J. S. Bevan, mayor of Atlanta:

Section of a well at the waterworks at Atlanta, Illinois.

	Feet.
Black soil	3
Yellow clay	15
Blue clay	10
Gray sand and gravel	10
Blue clay	2
Sand and gravel	9
White clay and sand	7
Blue clay with gas	3
White sand and gravel	10
Sand	6
Dry sand and gravel with gas	13
Blue clay	4
Clay, sand, gravel, and gas	16
Hardpan	9
Black drift (probably Peorian soil)	6
White clay (probably Iowan silt)	2
Green clay (probably Iowan silt)	4
Hardpan (probably Illinoian till)	10
Gravel and water	12
Total	151

The black drift noted in this well section has about the level of the plain outside the Shelbyville drift sheet, and is probably a soil formed above the Iowan silt.

In the vicinity of Delavan the drift over an area of several square miles may exceed 300 feet in depth, for the Shelbyville sheet here encroaches on a preglacial valley; the thickness in one well is 313 feet. The city waterworks well is 240 feet in depth and has the following section, furnished by J. D. Mount, city marshal:

Section of the well at waterworks in Delavan, Illinois.

	Feet.
Yellow bowlder clay (Shelbyville sheet)	15
Blue bowlder clay (Shelbyville sheet)	60
Black muck with wood (probably Peorian soil)	6
Soft green clay (probably Iowan silt)	8
Hard gray bowlder clay (probably Illinoian till)	30
Gray sand containing water	122
Total	240

The black muck penetrated in this well is at the base of the Shelbyville drift sheet. Mr. Mount reports that several wells in the vicinity of Delavan have encountered a similar bed of muck at this horizon.

Attention was called above to exposures along the Toledo, Peoria and Western Railway east of Peoria, and also on the east bluff of the Illinois opposite that city, where the Shelbyville sheet is underlain by a bed of fossiliferous loess similar in texture and in age to that found on the surface of the Illinoian drift outside the limits of the Shelbyville drift sheet. The loess is 8 to 12 feet in thickness, or about the same as on the uplands outside the Shelbyville sheet. It occurs at a corresponding elevation of about 200 feet above the Illinois River. Beneath it there is exposed fully 100 feet of the older drift sheet. The thickness of the Shelbyville drift sheet above this loess varies greatly, being in places but 20 feet, while elsewhere it is 75 or 100 feet. The variation is due in part to erosion and in part to original inequalities of thickness. As previously noted, these exposures afford excellent opportunity for contrasting the Shelbyville sheet with the older drift and for studying soils formed on the surface of the older drift.

In the portion of the Shelbyville moraine west of the Illinois River there are several wells 150 feet or more in depth which penetrate a blue till until the level of the base of this drift sheet is reached. In places its depth is more than 100 feet, and seldom does it fall below 70 feet. A large well was dug by William Dickison on the crest of the moraine 2½ miles west of Alta. The well entered blue till at less than 10 feet, which continued to a depth of 117 feet. Here a very bowldery bed 4 feet in thickness was passed through, under which a bed of loess was found, specimens of which were examined by the writer. Beneath the loess there is a hard pebbly clay, apparently Illinoian till, alternating with sand beds. Gravel containing water was struck at a depth of 156 feet. A well made by John Holmes, jr., one-half mile west of Alta obtained an abundance of water at 125 feet in gravel below till. But a boring made for John Holmes, sr., 1 mile east of Alta failed to obtain water, though it reached a depth of 370 feet. It apparently did not strike rock, but terminated in a fine sand. A bed of muck with wood and leaves was found at the remarkable depth of 245 to 247 feet. The sand below the muck is perhaps an alluvial deposit of pre-Illinoian age.

In the vicinity of Dunlap the best supply of water is obtained at 100 to 112 feet, in gravel and sand associated with the older drift. In the

village the base of the Shelbyville drift sheet is reached at 65 or 70 feet, and a few wells are obtained at this depth. A well at Harrison Harlan's, 2 miles south of Dunlap, at a level about 40 feet lower than the village, has a depth of 117 feet. It is mainly through the older drift, which is largely till, and water is obtained in sand and gravel at the bottom.

CHARACTER OF THE OUTWASH.

Considerable attention has been given the deposits and valley terraces immediately outside this drift sheet and on its outer slope in order to ascertain the character of the outwash. It is found that silt deposits, as well as sand and gravel, cap the surface of the outer face of the moraine and extend out onto the border plain. The silt deposits are loess like and fossiliferous, and suggest a feeble drainage. The sand and gravel deposits are very limited in their extent, and, on the whole, favor the view of feeble drainage. The amount of coarse outwash is very much less than is found to characterize the Bloomington morainic system, as is shown farther on. In some portions of the border the close association of silt and gravelly outwash renders the interpretation somewhat puzzling. The features can perhaps best be set forth by giving attention to each valley in turn which leads away from the Shelbyville sheet into the outer-border district, beginning with the Wabash Valley and proceeding westward.

In the vicinity of the Wabash Valley the Shelbyville drift sheet is found to be generally coated to a depth of several feet with a yellowish loess-like silt. This is especially well shown on the west side of the valley in the vicinity of St. Mary's, Indiana. This silt is better developed on the border of the river than at points a few miles back, there being scarcely enough silt in the latter situation to conceal the bowlders which cap the till. The distribution of the silt seems such as would be expected if drainage conditions were inadequate to carry off the water from the melting ice. There are, however, other features which seem to indicate good drainage conditions. At the point where the moraine crosses the river, near Atherton, a gravel plain is built up to a height of about 75 feet above the present stream, whose surface carries basins such as occur on gravel plains or terraces leading away from a moraine, and are found only near the moraine. There is at least a suggestion that this gravel plain is to be correlated with the Shelbyville moraine. This view is strengthened by the fact that the

material is very coarse at this point compared with that above or below, there being many bowlders, as well as cobblestones, embedded in the gravel. Were there no basins, the coarse material found in this portion of the terrace might be explained as a product of subsequent streams working upon the portion of the Shelbyville moraine which had been laid down within the valley, but the basins favor the view that this portion of the terrace is the product of the headwaters of a glacial stream. The removal of fine material from this terrace seems to indicate that there was good drainage at the time it was forming, a view which does not readily harmonize with the silt deposition along the valley.

Passing west to the Embarras Valley, which leaves the Shelbyville drift near the line of Coles and Cumberland counties, one finds evidence of a moderate discharge of water down the valley. The outer face of the moraine contains knolls of gravelly constitution in the immediate vicinity of the Embarras River, and among these knolls there are plane-surfaced tracts of gravelly material having the appearance of being the deposit of streams issuing from the ice margin. On the immediate borders of the Embarras Valley there is still better evidence of glacial outwash. Gravel deposits form a sheet which caps the till to a depth of several feet and which declines rapidly from the crest of the main ridge southward to the plain outside the moraine, occupying a very shallow valley in the passage down the slope of the moraine. Remnants of this gravel, preserved along the brow of the bluffs, stand 90 feet above river level at the northernmost point noted (2 miles north of the county line), and but 70 feet opposite the ford at the county line, and 45 feet at the south edge of the moraine about 2 miles farther south, and 35 feet above the river at the oxbow curve a mile farther south. The rate of descent is, therefore, about 10 feet to the mile more rapid than that of the present stream. At the north the gravel overwash stands 35 feet above the level of the base of the Shelbyville drift sheet, whose limits are here well defined by a white clay such as caps the older drift outside the Shelbyville sheet. At the south border of the Shelbyville drift the surface of the gravel stands 25 feet below the level of the white clay; it therefore cuts right down across the plane of the white clay. The valley of the Embarras above the south edge of the Shelbyville sheet has probably been excavated entirely since the Shelbyville drift was

deposited. The depth of the gravel deposits on the outer face of the Shelbyville moraine is but a few feet, seldom so much as 15 feet, and the gravelly belt, including the knolls as well as plane-surfaced tracts, has a width of scarcely more than 2 miles. The gravel has been carried but a few miles south of the limits of the moraine, there being only sand from the vicinity of Greenup southward in the terrace remnants found along the valley. These terrace remnants stand 20 to 40 feet below the border uplands and have apparently been built up at least from the level of the stream, 25 feet or more. The moderate transportation of gravel seems to indicate that the discharge was not vigorous and that drainage conditions were rather imperfect, except on the slope of the moraine.

Passing westward to the Kaskaskia Valley, which leaves the Shelbyville drift at the city of Shelbyville, one finds that the valley below the border of the moraine contains scarcely any deposits coarser than sand in the terraces built up during the Shelbyville or later stages. Light deposits of gravel were found on small tributaries at the points where they leave the Shelbyville drift sheet, but these are only a few feet in depth and are not, as a rule, continued down to the river valley. Within the limits of the moraine immediately above Shelbyville there is a terrace standing about 25 feet above the river which contains gravel and cobble. In places the gravel and cobble are found to rest upon till and to have a depth of but 8 or 10 feet. In other places the gravel apparently extends to the underlying shale, which, as shown by the bridge piers east of Shelbyville, sets in at 15 or 20 feet below low water. It is not entirely clear that this gravel and cobble was formed as an outwash from the ice sheet at the Shelbyville stage. On the contrary, it seems quite as probable that it is a residue resulting from the cutting down of the valley since the Shelbyville stage. In the process of cutting down, the coarse material would become concentrated while the fine material would be transported down the valley. In harmony with this view it is found that the surface of the terrace is somewhat below the level of the Shelbyville drift sheet and occupies a valley cut in that and the older drift sheet. The evidence from this valley, therefore, indicates a feeble outwash from the ice sheet at the Shelbyville stage.

The next valley of importance leading away from the Shelbyville drift sheet is that of the Sangamon River. Along this valley from the edge of

the Shelbyville sheet down as far as Springfield the terraces are composed of a gravelly sand with a few large pebbles. It is not certain, however, that these terraces should be correlated with the Shelbyville drift sheet, for they seem to be quite as well developed above the point where the river leaves the moraine as they do below that point. As indicated farther on, these deposits may be correlated with the Cerro Gordo moraine. At the point where the river crosses the Shelbyville moraine, south of Decatur, and also south of Harristown, the terrace remnants are found to lie in a valley cut to considerable depth into the Shelbyville sheet, and no over-wash gravels were found at higher levels. It should be stated, however, that, owing to the absence of wagon roads following along the valley and the inclemency of the weather at the time the writer was there, the valley was examined only at the two road crossings south of Decatur and south of Harristown. Further study at intermediate points or below Harristown may bring to light gravels which can be correlated definitely with the Shelbyville moraine.

Along the valley of Salt Creek, the first stream of importance issuing from the Shelbyville moraine north of the Sangamon River, a light deposit of gravel was found immediately outside the moraine on the road between Kenney and Hallsville, but the main deposits of the terraces along the valley are sand. This stream, like the Kaskaskia and Embarras, seems, therefore, to have carried only a weak discharge at the time the Shelbyville moraine was forming.

Two tributaries of Salt Creek—Kickapoo Creek and Sugar Creek—which cross the Shelbyville moraine farther north than the main creek, have their sources in the Bloomington morainic system and carry terraces whose head is found in that moraine. The valleys were not given sufficient study to enable the writer to determine whether they also have terraces which may be connected with the Shelbyville moraine. If such terraces are present, they are far less conspicuous than those which head in the Bloomington moraine.

On the Mackinaw River a terrace has been traced into connection with the Bloomington drift sheet, but none has been found which can be correlated with the Shelbyville. A deposit of loess several feet thick caps the Shelbyville moraine in the interval between the Mackinaw and Illinois

rivers, and also farther north and south, which, as above noted, seems to have been derived from the Shelbyville drift rather than brought by wind from the plain of Iowan loess on the west.

On Farm Creek, which enters the Illinois River opposite Peoria, and on small western tributaries of the Illinois just north of Peoria, as well as on the borders of the Illinois Valley in the vicinity of that city, there are gravel deposits which it is thought are derived in the main from the Bloomington moraine, though some of the deposits west of the river may prove to be connected with the Shelbyville. Those along Farm Creek may be traced with but slight interruption eastward into connection with the Bloomington moraine. These gravel deposits have a remarkably high altitude above the Illinois Valley, their elevation being about 175 feet above that stream on each side of the Illinois Valley at Peoria. It would seem, therefore, that the Illinois and its tributaries have been cut down this great amount at the point where the Shelbyville moraine crosses the river, since the Shelbyville stage, and probably since the Bloomington. However, the valley was apparently filled here to a greater height than at points above and below. A view of the gravel at Peoria is given in Pl. XIII. It is of medium coarseness, and in this respect harmonizes with that usually found in terraces that head in the Bloomington morainic system. It is coarser than is commonly displayed by the terraces that head in the Shelbyville drift sheet.

Kickapoo Creek and its tributaries, which lead away from the Shelbyville moraine in northern Peoria County, have terraces of sandy gravel which are doubtfully referred to the Shelbyville stage. They may prove to be simply incidents in the cutting down of the valleys through the somewhat sandy drift deposits outside the Shelbyville moraine. There appears to be no gravel terrace along Kickapoo Creek that can be correlated with the Bloomington moraine, though the stream heads in that moraine.

In view of the evidence just cited concerning the character of the outwash, it appears that in general it was weak, and it is doubtful if a vigorous outwash at any point can be proved.

INNER-BORDER TRACT.

TOPOGRAPHY.

The topography for some distance north and east from the border of the Shelbyville drift is of a gently undulating type, not markedly different from that of the thickened border. North and west from the Sangamon River there is a triangular tract included between the Shelbyville and Bloomington moraines in which swells 10 to 30 feet high are not uncommon, but no well-defined morainic belt has been found. East from the Sangamon River there are several small drift ridges lying between the Shelbyville and Bloomington moraines, but the greater part of the surface is plane. Aside from the ridges, the surface is less undulating than in the tract west of the Sangamon, just mentioned. These ridges are discussed individually and in some detail farther on.

THICKNESS OF DRIFT.

The Shelbyville till sheet covers this inner-border tract to a depth generally of 50 or 75 feet, and in places 100 feet or more. The depth seldom falls below 50 feet. It is usually not difficult to ascertain the thickness of the Shelbyville sheet, for well drillers report that it is much easier to penetrate than the underlying older drift. In the detailed discussion which follows, these differences are set forth.

STRUCTURE OF DRIFT.

In the district west of the Illinois River the Shelbyville moraine is separated from the Bloomington moraine by a narrow lowland, nowhere more than 3 miles in width, and running to a point in northern Peoria County and also at the border of the Illinois Valley. Apparently the drift beneath this lowland is mainly till and has considerable depth, one well having gone down 218 feet without entering rock. The well referred to is located on the farm of John Miller, 4 miles north of Dunlap. The well driller reports that the upper 69 feet was a soft till, mainly of blue color, and probably to be referred to the Shelbyville drift sheet. The remainder was a hard, brownish-gray till, apparently Illinoian.

Passing to the east side of the Illinois, we find the Shelbyville and Bloomington moraines closely associated at the east bluff of the river, but becoming separated within a few miles southeast to a distance of 10 or 12 miles. An interval of this width separates them from the Mackinaw River southeastward to Kickapoo Creek, near the meridian of Bloomington. The Shelbyville moraine there turns south and the Bloomington moraine turns east, thus leaving a wider interval between the two morainic systems. In the remaining 75 miles from the meridian of Bloomington eastward to the Indiana line the interval between these morainic systems is 40 to 60 miles. This interval, however, as stated above, is not entirely occupied by a plain, but is crossed by several drift ridges, which form the Champaign morainic system and the Cerro Gordo moraine, and these ridges are found mainly east of the Sangamon River. A wide tract west of that stream has a generally plane surface, with only occasional swells, and these but 10 to 30 feet or less in height.

This tract included between the Shelbyville moraine on the west, the Bloomington moraine on the north, and the Sangamon River Valley on the east, is underlain by a very thick deposit of drift. Records of several wells which penetrate more than 200 feet were obtained, and it is probable that the average thickness of drift exceeds 200 feet throughout the entire tract. The following represent the deepest wells of which records were obtained.

At the village of Morton the waterworks well terminates in sand at a depth of 230 feet, and three other wells within 2 miles northwest have about the same depth, and none reach the rock. The engineer at the waterworks states that for about 100 feet the drift is soft and easily penetrated, and is mainly of blue color. This, presumably, is the depth of the Shelbyville drift sheet. The next 100 feet is mostly a hard, gray till, though a bed of sand 20 feet in depth is included. The lower 30 feet is white sand.

At Hopedale, 12 miles south of Morton, near the inner border of the Shelbyville moraine, a well made by the railway company reached a depth of 195 feet. It was mainly till, except the lower 35 feet, which was a fine sand. A bed of black muck was passed through between till sheets, but the precise depth at which it occurred could not be ascertained.

In southwestern McLean County a few wells have reached a depth of 200 feet without entering rock, but the majority of tubular wells are 75 feet or less in depth. The Shelbyville drift sheet apparently has at least this

depth (75 feet), for the wells are entirely through soft till to the water-bearing gravel near the bottom.

In the vicinity of Heyworth inflammable gas is found in sand at depths ranging from 155 to 214 feet. The strongest well is located on the farm of J. C. Wakefield, three-fourths of a mile southeast of the village, and has the following section, reported by the driller, Mr. Gault:

Section of Wakefield's gas well near Heyworth, Illinois.

	Feet.
Till (Shelbyville sheet)	33
Gravel and sand (probably Shelbyville)	69
Hard clay with no pebbles or grit	36
Sand	15
Hard blue clay	35
Hard clay with no grit	11
Black muck	2
Hard gray clay without grit	13
Sand and gravel with gas.	
Total depth	214

When the gas was struck, sand and gravel were blown out of the mouth of the well, and the well now has a pressure of 22 pounds to the square inch from a 2-inch pipe, and supplied fuel for 200 stoves during the winter of 1896–97.

At Wapella, a village 6 miles south of Heyworth, the deep tubular wells penetrate about 80 feet of soft blue till referable to the Shelbyville drift sheet. Beneath the blue till is a bed of black muck, probably Peorian, with a green clay, apparently a swamp subsoil, underlying it. This is perhaps an Iowan silt. Beneath the green clay is a hard bowlder clay, referred to the Illinoian. Many of the wells are obtained at the base of the Shelbyville sheet at 65 to 80 feet. Those which reach a greater depth obtain their supply from sand associated with the older till, and the sand not infrequently yields a considerable amount of gas.

At Leroy, in southern McLean County, the waterworks supply is from a well 110 feet deep, which obtains its water from sand below the till of the Shelbyville sheet. Wells are occasionally sunk in that vicinity to a depth of nearly 200 feet and penetrate a large amount of sand in the lower portion.

At Farmer City the waterworks supply is from a well 176 feet in depth which does not reach the rock. It is mainly through till, but there are

several beds of sand and gravel associated with it. A prospect boring for coal made at this city penetrated 189 feet of drift, as follows:

Section of boring for coal at Farmer City, Illinois.

	Feet.
Black soil	2
Yellow till	9
Blue till	36
Sand and water	2
Blue till	21
Sand and gravel	40
Blue clay	6
Sand and gravel	8
Sandy blue clay	40
Sand and gravel	23
Blue clay	2
Total drift	189

Several interesting well sections and bluff exposures are found along the west side of the Sangamon River below Mahomet. About $1\frac{1}{2}$ miles southwest of this village, in sec. 16, T. 20, R. 7 E., the river exposes in its northwest bluff a bed of peat under the Shelbyville till sheet. The exposure is several rods in length and the section is as follows:

Exposure in bluff of Sangamon River near Mahomet, Illinois.

	Feet.
Yellow till with gravelly places near base, where springs issue	10–12
Gray till with yellowish tinge	20
Peat, earthy except 3 to 6 inches at top	2
Gray earthy subsoil, exposed	2– 3
Total, to river bed	36

It is probable that the Shelbyville sheet is reduced at this place to a thickness of only 30 to 32 feet, as the altitude near the river is slightly lower than the general level of the border plains. Wells between this exposure and Mahomet pass through a black muck or peat at about the same level as that exposed along the river. One on the farm of James Lester strikes it at 36 feet, and one at the residence of D. McArthur at 42 feet. Mr. McArthur's well was continued to a depth of 100 feet and penetrated a harder till below the black muck than that which overlies it. There are places between this exposure and Mahomet where the entire bluff is composed of gravel. It is principally on the farm of Mr. Lester, and he has tested its extent by means of borings and found that it underlies only 60 acres. Around the gravel on all sides except at the southeast, where it fronts the river, there is till. Its depth is found to reach 50 or 60 feet in

places. Its surface has about the same altitude as the bordering till plain, 35 feet above the Sangamon River.

At Dalton City, located about 12 miles southeast of Decatur, the bottom of the Shelbyville drift sheet is found at 65 feet, and wells have been sunk to a depth of 150 feet without reaching rock. The majority of wells are about 70 feet. It is not uncommon to find beds of black muck below the Shelbyville drift in the vicinity of this village.

At Bethany, 5 miles southeast of Dalton City, the Shelbyville sheet is apparently only 40 feet in depth. At this depth a greenish clay, associated in places with a black mucky soil, is usually entered. This clay is but a few feet in depth, and is probably an Iowan silt. It is underlain by a hard gray till, called hardpan, which seems to be Illinoian. The tubular wells in that vicinity range in depth from 70 to 140 feet without striking rock.

At Sullivan the drift, as shown by records published in the Geology of Illinois, has a depth of about 200 feet. The public water supply is from wells 100 to 125 feet in depth. The mayor reports that the upper 50 feet is a soft blue till, beneath which considerable sand is penetrated. This is underlain by a hard till which is penetrated 40 feet or more before the water-bearing gravel is reached.

In northern Coles County, between Humboldt and Fair Grange, wells are 60 to 120 feet in depth without reaching rock. In some wells a hard gray till is struck at about 50 or 60 feet. The overlying till is soft and probably is referable to the Shelbyville sheet. At Oakland, in northeastern Coles County, rock is entered at about 50 feet.

At Kansas, in western Edgar County, rock is entered at 80 feet or less. In a few cases wells have struck a black soil at about 30 feet, which is probably just below the Shelbyville drift sheet. A well midway between Kansas and Isabel entered rock at only 40 feet, but others in that vicinity 50 feet or more in depth do not strike rock. In the eastern part of Edgar County, on Clay's Prairie, rock is occasionally struck at only 20 or 25 feet, and is extensively exposed along Bruillett's Creek, in eastern Edgar County, Illinois, and southern Vermilion County, Indiana. The general thickness of the drift in that region can scarcely exceed 40 feet.

The Indiana district, immediately north from the Shelbyville moraine, has generally a comparatively thin sheet of drift on the uplands, rock often being struck at 50 feet or less, but in the preglacial valleys the drift may

exceed 150 feet in thickness. As there are several moraines crossing this district the discussion of its features is taken up in connection with them on later pages

CERRO GORDO MORAINE.

DISTRIBUTION.

The Cerro Gordo moraine emerges from beneath the Champaign moraine opposite the village of Mahomet, in Champaign County, and follows the east border of the Sangamon River Valley, at a distance of 1 to 3 miles from the stream, from Mahomet southward to Cerro Gordo, a village 10 miles east of Decatur. It there swings away from the river, and is distinctly traceable only to Laplace, 6 miles south of Cerro Gordo, there being for a few miles no definite continuation. A distinct ridge, however, appears near Humboldt, in northern Coles County, which is supposed to be its continuation. This ridge is traceable in a general eastward course, but with slight windings, through southeastern Douglas and central Edgar counties.

The interval between the Cerro Gordo and Shelbyville moraines varies greatly in width. Near the city of Paris they are closely associated; at Humboldt they are separated by a space of 10 or 12 miles, and a similar interval is found opposite Cerro Gordo. From Cerro Gordo northward the ridges pursue divergent courses, so that opposite Mahomet they are separated by a space of 25 or 30 miles.

TOPOGRAPHIC EXPRESSION.

The portion of the moraine between Mahomet and Laplace consists of an irregular aggregation of drift swells and short ridges, occupying a belt about 2 miles in average width. The knolls are so closely aggregated that very little plane surface is found among them. The usual height is 10 to 20 feet, but a few are 30 feet or more above bordering low ground. The belt is sharply in contrast with the level tract to the east, and has on the whole a stronger expression than the Shelbyville moraine.

The portion leading eastward from Humboldt presents more variation in topography than the portion just mentioned. In northern Coles and southeastern Douglas counties, and for several miles in western Edgar County, it consists of a smooth till ridge one-half mile to a mile in width, with a relief of 20 to 30 feet. In places it is but 60 to 80 rods wide, and

stands only 10 to 15 feet above the border plain. The ridge is nearly continuous except at the Embarras River, which cuts through it opposite Dora Station. In Edgar County the belt has, on the whole, a stronger expression, though there is not so continuous a ridge as in Douglas and Coles counties. There are several small ridges, one-fourth mile or less in width and 10 to 20 feet in height, which form a disjointed chain leading southeastward from Brocton to Paris. Associated with these there are knolls of considerable prominence. A cluster in secs. 15, 16, and 17, T. 14, R. 12 W., known as the Blue Mounds, rise 50 or 60 feet above the border plains. An isolated knoll in sec. 32, T. 15, R. 13 W., is about 50 feet in height and occupies perhaps 20 acres. North and northwest from this knoll, in secs. 29 and 30, several knolls rise abruptly to a height of 20 or 30 feet, and one to a height of 40 feet. In the northeast part of Paris there is a ridge leading from Sugar Creek southwestward about 1½ miles, which is 30 to 50 feet in height and has a billowy surface. Its width is 40 to 60 rods. Probably this ridge belongs in the belt under discussion, though it is slightly out of line with the belt and is separated from it by a plane tract about 2 miles in width. Toward the northeast there are occasional knolls as far as the State line, but no definite ridge or chain of knolls appears. The well-defined belt terminates at the Blue Mounds.

STRUCTURE OF THE DRIFT.

Some of the sharper knolls of the moraine contain gravel and sand, especially along the border of the Sangamon River and in Edgar County. There is, as a rule, considerable till associated with the gravel and sand, and the knolls are usually underlain by a sheet of till. The gentle swells and the smooth ridges are composed more largely of till than those of sharper contour.

The majority of wells along this belt obtain their supply at a level little, if any, below the base of the knolls and ridges and within the limits of the early Wisconsin drift sheets. A few pass into the older drift. Very rarely a well reaches the rock. The drift, as in the tract outside the moraine, is very thick in Illinois except in the vicinity of the State line, but is thin in Indiana. The following are the deepest wells of which records were obtained:

On H. H. Hollis's farm, in sec. 30, T. 20, R. 7 E., a well is 215 feet in

depth, and on B. F. Hollis's farm, in sec. 31, two wells are 190 feet in depth, without reaching rock. The drift is largely a blue till and but a small part is thought to belong to the early Wisconsin. It is described to be mainly hard till below a depth of 40 feet. F. G. Seymour has a well in sec. 6, T. 19, R. 7 E., 215 feet in depth, which is similar to the wells on the Hollis farms.

At Monticello the city water supply is from two wells 212 and 303 feet in depth, neither of which enters rock. The early Wisconsin drift here is apparently but 20 feet thick, the wells being on low ground near the Sangamon River. The following is the record of the deeper well as published in the Piatt Independent soon after the completion of the well in 1891:

Section of a waterworks well at Monticello, Illinois.

	Feet.
Black loam	3
Yellow clay	10
Blue clay (gravelly)	7
Brown peaty loam (Peorian?)	7
Sand and gravel	2
Blue clay	11
Sand, gravel, and water	5
Silt	12
Sand, gravel, and water	55
Hard blue clay (pebbly "hardpan")	49½
Quicksand	75½
Sand and gravel	64
Coarse gravel	2
Total	303

In the veins of water above the "hardpan" the water is less suitable for culinary and laundry purposes than in those below, because of greater hardness. Both wells are, therefore, sunk to a coarse gravel in the lower water bed.

At Bement a well in the business part of town struck rock at 222 feet and is 225 feet in depth. Wells at the waterworks, the railway station, and the mill obtain a good supply of water at 140 to 150 feet, after penetrating a large amount of blue till. It is not certain that the Wisconsin drift has so great a depth as 150 feet at this point, the records of wells being imperfect. At the cemetery, 2 miles north of Bement, near the crest of the Cerro Gordo moraine, a well 221 feet in depth is mainly through blue till and does not reach rock.

At Cerro Gordo there is a nearly solid bed of blue till to a depth of 150 feet, and strong wells are seldom obtained at less depth. That the

Wisconsin drift has a depth of 150 feet at this point is supported by the fact that the moraine there reaches an altitude nearly 150 feet above the level of the buried soil along the Sangamon Valley at Monticello and near Mahomet.

Along the ridge from Humboldt eastward into Douglas County wells apparently reach the base of the Wisconsin drift at 65 to 75 feet, and farther east at 50 feet or less.

The sharp ridge situated in the northeast part of Paris has been opened extensively for gravel. There is at the surface a brownish yellow till 5 to 15 feet thick, and beneath this are beds of calcareous sand several feet in depth. Beneath the sand there is a sandy gravel. Both the sand and the gravel show considerable cross-bedded structure. The beds are also arched, and appear to have been crumpled somewhat as if by a disturbance by the ice sheet. In order to ascertain the proportion of the various kinds of rock in this gravel, a small space was marked off in the gravel pit and the pebbles therein were classified, with the following result:

Classification of pebbles in a gravel pit at Paris, Illinois.

Granite	6
Other crystalline rocks	8
Quartz	3
Chert of light color	13
Brown chert	1
Carboniferous sandstone (local)	11
Gray limestone (probably local)	45
Magnesian limestone	48
Total	135

A few of the gray limestone pebbles are striated. These pebbles show less rounding by water action than other classes. It is probable that some of them are from the Carboniferous limestone exposed near Baldwinsville, north of Paris.

CHARACTER OF THE OUTWASH.

The character of the outwash from the Cerro Gordo moraine has received very little attention. It has been noted, however, that the valleys leading away from the moraine, with the exception of the Sangamon, are small and are usually cut in till. There can not, therefore, be very heavy sand or gravel outwash.

Along the Sangamon River for a few miles below Mahomet this morainic belt is bordered on the west by a gravelly plain, whose origin and

relationships are not fully determined. It may be due largely to the cutting down of gravelly portions of the Shelbyville sheet, such as that near Mahomet just noted. It stands about 20 feet above the Sangamon River, or about halfway from the level of the river up to the level of the till plain on the west. In places the morainic knolls east of the river extend down to the level of this gravelly plain, and seem to be merged with it so intimately that there is a strong suggestion of similarity in age. However, it is not fully established that even in such places the gravel is an outwash from the moraine. As shown below, there is a light gravelly outwash near Mahomet from the Champaign moraine over the till plain that borders it on the south. It is possible that the gravel plain along the valley was built up in part at that time, though the lightness of the deposit at Mahomet scarcely warrants the reference of a large part of the filling to this source.

INNER BORDER TRACT.

Between the Cerro Gordo moraine and the outer ridge of the Champaign morainic system there is a plain whose width nowhere exceeds 25 miles and usually is about 12 or 15 miles. This plain has a very level surface, there being few swells or knolls and but little variation in altitude. It is underlain by thick deposits of drift, except for a few miles near the State line. Wells indicate that it may average nearly 200 feet, of which probably more than one-half is older than the Shelbyville sheet. Since the majority of wells obtain water without reaching the base of the Shelbyville sheet, few data concerning the older drift are available from this region, but inferences may be drawn to some extent from neighboring districts on either side, where the data concerning thickness of the drift are more full.

Wells in the vicinity of Arcola are reported to have passed from the soft till of the Shelbyville sheet into a harder till, presumably of the older drift, at a depth of only 45 or 50 feet. In the vicinity of Tuscola the wells usually pass from the soft till of the Shelbyville sheet to a harder till, termed hardpan, at a depth of 35 to 40 feet. A prospect boring for coal at Tuscola penetrated 186 feet of drift. It is probable that the thickness of the Wisconsin drift is somewhat greater on the portion of the plain to the west of these towns, as shown by records outside the Cerro Gordo moraine already given. The thickness to the east of these villages is probably less rather than greater than in their vicinity, there being a general decrease in thickness in that direction.

SECTION II. CHAMPAIGN MORAINIC SYSTEM.

Under this head is discussed a group of closely associated ridges which interlock to some extent, but usually consist of two or three distinct members. The system receives its name from the city of Champaign, Illinois, the site of the State University. The ridges, which are more or less distinct east from this city, become united in a single ridge from this city westward. The discussion begins at the westernmost point at which the system has been recognized, and proceeds eastward to the point of disappearance beneath a morainic system of late Wisconsin age. In the complex portion separate names have been applied to the several members, viz, Outer or West Ridge, Middle Ridge, and Inner Ridge

DISTRIBUTION.

The westernmost prominent development of the Champaign morainic system is found in "Blue Ridge," which sets in near the village of Blue Ridge, in northern Piatt County, and leads southeastward into Champaign County. There is, however, a narrow belt, with rather more undulation than is common on till plains, which leads westward from near the north end of Blue Ridge past Leroy to the Bloomington moraine at Downs, and which is doubtfully referred to the Champaign morainic system. This undulatory belt stands 20 to 30 feet or more above the general level of the plain on the south, but the rise is so gradual that the relief is scarcely perceptible.

The portion known as Blue Ridge comes to the Sangamon River just above Mahomet. With a gap scarcely one-half mile wide the moraine reappears on the east bluff, and leads southeastward to Champaign, crossing the Cleveland, Cincinnati, Chicago and St. Louis Railway west of the city. The width from Blue Ridge to Champaign averages about 2 miles.

A short distance west of Champaign the Outer or West Ridge separates from the main belt and passes southward through Savoy and Tolono to West Ridge village, in Douglas County, near which it swings rapidly eastward and joins the middle member of the series in southwestern Vermilion County. This ridge has an average breadth of scarcely one-half mile in its north-south portion, but in the west-east portion it increases to a width of nearly 2 miles and becomes the principal ridge of the series.

From Champaign a ridge nearly as bulky as the combined belt leads southeastward through Philo. A short distance southeast of this village it separates into two quite distinct ridges. One continues the southeast course past Broadland and joins the outer ridge in southwestern Vermilion County. The inner ridge passes eastward into Vermilion County along a line nearly parallel with, and about 2 miles south of, the Wabash Railway until it reaches the meridian of Fairmount, where it turns southeastward. It comes to Little Vermilion River east of Georgetown and follows the north side of that stream to the Wabash Valley. East of the Wabash its course is northeastward to Veedersburg, and thence eastward into western Montgomery County, where it is overridden by a late Wisconsin moraine and its further course lost to view. This ridge throughout its entire length is narrow and low, seldom exceeding one-half mile in width, and rising but a few feet above border plains. It is also scarcely so continuous as the other members of the series. From Veedersburg another weak drift ridge leads northward past Rob Roy to the Wabash Valley near Attica, beyond which it can not be traced, because of concealment beneath later moraines.

Returning to southwestern Vermilion County, where the Middle and Outer ridges become united, and tracing their further course, one finds a ridge about 2 miles wide and 50 to 100 feet high passing eastward near the line of Vermilion and Edgar counties into Indiana. In places it has a double crest, but in other places it is a thoroughly combined belt. For a few miles on the west side of the Wabash River it is not well defined, but it is easily located on the east bluff just below the mouth of Sugar Creek. Its course for about 8 miles is south of east. It there curves, near the village of Bloomingdale, and takes a nearly northeast course, crossing Sugar Creek at a narrow gorge known as "The Shades of Death" near the line of Parke and Montgomery counties. In western Montgomery County near the village of Alamo, which stands on its crest, the course is again changed toward the north, and it trends nearly due north to where it is overridden by a moraine of the late Wisconsin series, near Wesley, Indiana.

The course of the members of the Champaign system is such that the Inner Ridge is separated from the combined Middle and Outer belt by a space 15 to 20 miles in width in the district immediately east of the Wabash, while west from that valley the space is 10 miles or less. The

Outer Ridge at its widest separation from the Middle one is distant but 8 or 9 miles. It is separated from the Middle Ridge for only about 30 miles of the 100 or more miles in which they are exposed to view. The Inner Ridge is distinct from the others for a much longer distance, being combined with them for only about 30 miles of the 100 which the belt occupies.

It will be observed that the moraines are looped across the Wabash Basin after the fashion of the looping of the late Wisconsin moraines about the basins and large valleys, as brought to notice by Chamberlin in the Third Annual Report of this Survey. The axis of the Wabash Basin is depressed only 150 to 200 feet (aside from the immediate valley of the river) below the borders of its watershed where crossed by this morainic system. This slight amount of depression seems scarcely adequate to be the sole cause for the protrusion of the ice sheet into the valley, though it no doubt had some influence.

RELIEF.

The relief of the combined belt between Blue Ridge and Champaign reaches about 90 feet above the outer-border plain at several points, though it usually is about 60 to 75 feet. The outer-border plain declines from 750 feet at Blue Ridge to about 710 or 720 feet east of the Sangamon. The crest of the moraine reaches 820 feet in northern Piatt County, and 800 to 810 feet near Rising in Champaign County, but averages only about 775 feet above tide. The inner-border plain lying north of this portion of the moraine stands about 730 feet above tide.

The outer ridge has a measured relief of 45 feet on the outer border and 40 feet on the inner border at the crossing of the Wabash Railway at Tolono, but at the crossing of the Chicago and Eastern Illinois at West Ridge it scarcely exceeds 35 feet on either border. Farther east, near its junction with the Middle Ridge, the relief increases to 70 feet, and one point near Palermo, used by the United States Lake Survey as a site for a geodetic station, stands 90 feet above the general level of the outer border plain.

The Middle Ridge has a relief of 25 or 30 feet on its outer border throughout the interval in which it is distinct from the Outer Ridge. On its inner border the relief is about 20 feet. At Philo, where the Inner and Middle ridges are combined, the outer-border relief, as shown by the

Wabash Railway survey, is 30 or 35 feet, while the inner-border relief is about 50 feet. The relief of the Inner Ridge throughout its entire course in Illinois and Indiana is but 15 to 20 feet, except where knolls rise above the general level of the crest. In such cases a relief of 40 or 50 feet may be found. The combined Middle and Outer ridge has a general relief in eastern Illinois of about 40 feet above the outer-border plain and about the same relief above the inner border. Where there is a double crest, the sag between the crests is 15 to 25 feet in depth.

In the Indiana portion the relief seldom reaches 40 feet, and the average is probably 30 feet above the plains on the outer and inner border.

It appears from the data just given that the outer and inner border reliefs in this morainic system are not markedly different. There is not such a filling on the inner border and transition from the moraine into the plain as in the Shelbyville or Cerro Gordo moraines. As seen in profile, the ridges of the Champaign system rise with nearly as rapid slope on the inner as on the outer border, a feature which distinguishes them from nearly all of the moraines of the Wisconsin series, it being the habit of the Wisconsin moraines to present a long inner slope and a somewhat abrupt outer slope.

RANGE IN ALTITUDE.

As indicated above, the moraine, near the western end, attains an altitude of 820 feet above tide, while the border plains are about 750 feet. The altitude of the plains decreases to about 700 feet in southern Champaign County and to 660 feet in the vicinity of the Embarras River, in northern Douglas County. From this point eastward to the borders of the Wabash the plains stand 650 to 675 feet along the border of the combined Middle and Outer ridge. The altitude is less uniform along the line of the Inner Ridge, there being a range of about 75 feet in the Illinois portion. The highest part of the plain near Sandusky is fully 720 feet above tide, while in the western part of the county it scarcely reaches 675 feet, and in the eastern it falls to about 650 feet. On the borders of the Wabash in western Indiana the altitude of the upland plain declines to about 600 feet. There is a gradual rise from the valley eastward to 775 or 800 feet in western Montgomery County, where the moraines of this system pass beneath a moraine of the late Wisconsin series.

SURFACE CONTOURS.

On the whole the ridges of this system are of a type which may best be designated the smooth-ridge type, the surface undulations being very gentle, while the crest is usually well defined. A detailed examination, however, brings to light considerable variation in the features.

The portion west of the Sangamon River, known as Blue Ridge, has a well-defined crest, along which undulations of 10 to 20 feet occur. On its slopes also there are gentle swells 5 to 15 feet in height. In the vicinity of the Sangamon River a few knolls of greater prominence appear, though the highest scarcely rise more than 40 feet above bordering low ground. Between the Sangamon River and Champaign the moraine presents a well-defined crest and undulatory slopes. The undulations commonly fall below 20 feet, both along the crest and on the slopes. The outer face is more abrupt than the inner, there being places where a rise of 50 feet is made within a mile from the border of the plain outside the moraine.

The Outer Ridge from the city of Champaign around to northeastern Douglas County has a very smooth surface, in which undulations seldom exceed 10 feet. The relief of 20 to 40 feet, however, makes the ridge a noticeable feature. In passing eastward through northern Douglas County the ridge becomes much larger, but maintains a nearly smooth surface. A short distance west of its junction with the Middle Ridge it presents a double crest, but each ridge is very smooth.

The belt leading southeast from the city of Champaign presents swells 15 feet or more in height, but the crest is ill defined between the city of Champaign and sec. 33, Urbana Township. From this section southeastward, through Philo Township, and thence eastward to sec. 4, Raymond Township, the crest is well developed. It has oscillations of from 10 to 25 feet, and the slopes are characterized by knolls of similar elevation. In the vicinity of Lynn Grove geodetic station knolls and sharp winding ridges 30 or 40 feet in height occur, and the moraine maintains this strength of expression for about 3 miles east from the geodetic station. It there loses strength, and in northeastern Raymond and South townships, Champaign County, and in Sidell Township, Vermilion County, it consists of a smooth ridge scarcely 20 feet higher than the plain south of it. North of this

ridge there are scattering knolls surrounded by very level tracts. One knoll near the line of secs. 1 and 2, Raymond Township, covers not less than 10 acres and has a height of probably 30 feet. Other knolls 10 to 25 feet in height were observed. The Middle Ridge does not connect closely with the Outer Ridge in southeastern Champaign and southwestern Vermilion counties, but is separated from it by a sag or depressed tract a half mile or less in width. This depression connects on the east with the Little Vermilion River and on the west with the Nile, a tributary of Embarras River.

For about 5 miles eastward from the Palermo geodetic station a single broad ridge, 1½ to 2 miles wide, constitutes the equivalent or continuation of the two ridges found farther west. It does not long continue the sole representative, however, for another ridge sets in just north of the headwaters of Bruillett's Creek, in sec. 4, T. 16, R. 12 W. From this section eastward nearly to the State line there is a double ridge, the members of which are nowhere separated more than one-half mile. Mortimer stands on the outer and Ridge Farm village on the inner of these ridges. A few basins occur along the ridges in southeastern Vermilion County, the deepest of which are depressed 8 or 10 feet below bordering land and are occupied by peat bogs. The ridges have gentle undulations of 10 to 20 feet, both along the crest and on the slopes. The Outer Ridge has interruptions or gaps which afford a passage for waters which fall between the two ridges southward to the outer-border plain. The gap through which Bruillett's Creek passes is nearly 75 feet in depth and less than one-half mile in width. Several other gaps of less depth occur, all of which are quite narrow. They appear to have been deepened considerably by the streams which pass through them. The two ridges become coalesced at Pilot Grove, a prominent point in sec. 33, T. 17, R. 11 W. From this grove eastward to the State line, knolls and ridges rise from the crest and slope somewhat abruptly to heights of 15 or 20 feet, and give the moraine a sharper expression than is usually displayed. From the State line eastward to the Wabash River the bulk as well as the expression, decreases, the crest becomes poorly defined, and the undulations are scarcely 10 feet in height.

For a few miles east of the Wabash River the moraine is represented by knolls only, there being no well-defined ridge or crest line. The most prominent knolls observed are in sec. 17, Reserve Township, Parke County.

They are somewhat elongated in a NW.–SE. direction, and rise abruptly to a height of 20 or 30 feet. Farther east, in the vicinity of Bloomingdale, the knolls are in some cases 30 feet or more in height. In secs. 24 and 19, 25 and 30, T. 16, Rs. 7 and 8 W., the moraine consists of a ridge 80 rods to a mile or more in width, on whose slopes and crest knolls 10 to 25 feet in height are numerous. Outside the main ridge there is, in sec. 29, a chain of knolls 15 to 20 feet high, rising abruptly above the bordering plane tract. In eastern Parke County the moraine for a distance of about 10 miles constitutes the water parting between Little Raccoon and Sugar creeks, and there is scarcely a mile of this portion on which knolls 15 to 25 feet high do not occur, while in some sections they reach heights of 30 or 40 feet. These knolls stand upon a basement ridge whose relief, independent of the knolls, is 30 or 40 feet. In this part of the moraine the knolls are arranged in chains trending parallel with the crest. In southwestern Montgomery County, on the south side of Sugar Creek, there are numerous sharp knolls in the moraine, but not a distinct ridging or well-defined crest. North of Sugar Creek the moraine assumes a ridged form near the south line of sec. 34, T. 18, R. 6 W., from which point the ridge leads NNE. through Alamo. Its general height is about 30 feet above the plain west of it, and still more above the bluff of Sugar Creek Valley on the east. Near Alamo, in secs. 23 and 26, several basins occur, the deepest of which are 15 or 20 feet below their bordering rims. The basins usually have outlets through narrow breaks in the rim. West of the main belt for several miles the surface is very flat, but east of it there are ridges and knolls extending to the valley of Sugar Creek. The knolls are nearly as prominent as those in the main belt, but are less closely aggregated. They are separated by nearly plane tracts. The northeast fourth of Ripley Township, comprising a tract 3 or 4 miles wide, is sharply undulatory, with many knolls and ridges 20 to 40 feet high. The moraine here is overridden by a late Wisconsin moraine. The latter trends NNW.–SSE., intersecting the Champaign moraine at an angle of about 45 degrees.

The Inner Ridge of the Champaign morainic system is well defined from its point of separation from the Middle Ridge, near Philo, Illinois, eastward to the Fairmount geodetic station. It is about one-half mile in width and 20 feet in height, and presents a gently undulating surface. South and east from the geodetic station there is a series of knolls and

short, rather sharp, ridges. The most prominent ridge traverses secs. 25, 26, and 36, T. 18, R. 13 W., and its highest points stand fully 50 feet above the bordering plain, yet its width, including slopes, is scarcely one-half mile. A lower ridge passes north-south through secs. 16 and 21. In secs. 9 and 10 also there is a low ridge which trends WNW.–ESE., and stands perhaps 20 feet above the bordering plain. Blue Mound, a sharp knoll in sec. 11, stands 55 feet, by aneroid, above the border plain and covers about 30 acres. In secs. 10 and 15, T. 18, R. 12 W., a well-defined undulatory ridge occurs which carries shallow basins on its crest and slopes. There are several knolls 10 or 15 feet high in secs. 7 and 18 of this township, which should probably be referred to this morainic belt. From Blue Mound, in sec. 11, T. 18, R. 13 W., to sec. 27, T. 18, R. 11 W., a distance of 10 miles, only occasional low ridges and knolls are to be seen, the highest of which rise scarcely more than 15 feet above the bordering plain. But from sec. 27 southeastward to the Wabash River bluff near Eugene, Indiana, a distance of 7 to 8 miles, there is a well-defined ridge, about a half mile in width, whose highest points rise 40 feet or more above the bordering plain, while its lower points seldom fall below 20 feet. It carries winding ridges and sharp knolls on its surface, among which shallow basins are inclosed.

East from the Wabash River this moraine has, as a rule, a gentle swell-and-sag topography, with undulations of 10 feet or less and a relief of scarcely 20 feet. In the vicinity of Rynear, however, in secs. 2 and 3, T. 19, R. 7 W., there is a chain of knolls standing 20 to 40 feet higher than the plain on the north, and occupying a belt about a half mile in width. The Cleveland, Cincinnati, Chicago and St. Louis Railway passes over a spur from this ridge just east of Rynear, while west of the village it passes through a gap in the ridge. In sec. 9 the ridge takes a NE. to SW. trend and is distinctly traceable to the southwest part of the section. The remainder of this belt consists of knolls more or less closely aggregated but seldom exceeding 10 feet in height.

The weak belt leading northward from Veedersburg to Rob Roy has no prominent knolls except in the northern portion. The slight undulations which it presents, however, are in decided contrast to the very flat surface of the plain on the west. Although the moraine has but feeble expression its relief is sufficient to cause the southward deflection of Coal

Creek. The slope of the country is such that the creek would have continued directly westward to the Wabash and reached that river in about 6 miles from the point where it encounters the drift ridge, but the deflection occasioned by the drift ridge makes it necessary for it to flow not less than 25 miles before reaching the Wabash. At the northern end of the ridge, near Rob Roy, knolls 20 to 30 feet high occur, and points in sec. 25, T. 21, R. 8 W., stand 50 or 60 feet above the bordering plain. To give added morainic expression these prominent points are thickly strewn with bowlders.

THICKNESS AND STRUCTURE OF THE DRIFT.

The thickness of drift in this morainic system is to be measured by the relief of its ridges rather than by the distance to rock, for beneath the level of the base of the ridges older sheets of drift occur. The relief, as shown above, nowhere reaches 100 feet and seldom exceeds 50 feet. The distance to rock, on the other hand, rarely falls below 50 feet along the line of the ridges, and in places is known to be 300 feet. In the Indiana portion and in eastern Illinois, for some 20 miles west of the State line, rock is usually entered at 100 feet or less, and there are numerous rock exposures along the principal streams. Farther west the rock surface lies lower, and the few borings which reach the rock indicate that the average thickness of the drift in Champaign, Piatt, and McLean counties is not less than 200 feet, while the maximum thickness is fully 300 feet.

These morainic ridges are composed in the main of till. Gravel and sand beds are occasionally found in the knolls and near the level of the base of the ridges, but even in these situations they are of comparatively limited extent. Along this morainic system in Indiana there is sufficient gravel in the knolls to supply material for improving the roads in their vicinity, but in Illinois road material is generally difficult to obtain. Gravelly knolls were observed east of Ridge Farm village and on the inner slope of the moraine near Champaign and Urbana. Along the sharply ridged portion of the inner ridge in the vicinity of the State line, and also in the sharp knolls near Fairmount, there is considerable gravel associated with the till. It is possible that many knolls contain gravel which has not yet been discovered. On the whole, water-bearing beds are more extensive in the Indiana portion of these morainic ridges than in the Illinois portion. In the latter district wells are often sunk to a level below the base of these

drift ridges before water can be obtained, while in Indiana, water-bearing beds are usually found before reaching the base of the ridges.

This morainic system is characterized by a limited number of surface bowlders, and a moderate number are incorporated with the till. The majority of the surface bowlders are crystalline rocks of Canadian derivation. They are usually subangular and seldom show striated faces. As in the drift sheets of this region generally, the bowlders incorporated in the till appear to be much more frequently glaciated than those on the surface. There is also apparently a larger proportion of limestone rocks of local or semilocal derivation embedded in the till than are found on the surface.[1]

Several large blocks of limestone, however, were found on the surface in Champaign County, Illinois. At George Stewart's, a few miles southeast of Philo, on a prominent portion of the ridge in sec. 4, T. 17, R. 10 W., two large limestone blocks were examined by the writer. They are of gray color and contain Pentamerus shells, apparently of Niagara age. Mr. Stewart has dug to a depth of about 4 feet at the side of one of the rocks without reaching its base, and it has a surface exposure nearly 10 feet square. The other block has been uncovered for a space of about a square rod and extends some distance beneath the ground. The nearest known outcrop of this rock formation toward the north (the direction from which the ice came) is in northern Iroquois County, some 60 miles distant.

In Indiana the district traversed by these moraines and the morainic ridges themselves are characterized by few surface bowlders, except in northwestern Montgomery and northeastern Fountain counties. They there abound on the plains as well as on the ridges. It seems probable, however, that these bowlders are to be connected with the late Wisconsin ice invasion, though their position is such as to throw them outside a regular border of the ice sheet. The bowlders apparently connect on the north with well-defined bowlder belts of late Wisconsin age which lead northward from the Wabash River near Williamsport. Whether the bowlders on the group of knolls near Rob Roy referred to above were deposited by this later invasion is uncertain. It is also not entirely certain that these knolls are independent of the later invasion.

The surface of the ridges of the Champaign morainic system, as well as the plains between them, is commonly covered with a pebbleless clay

[1] For discussion of these features see Chamberlin: Jour. Geol., Vol. I, 1893, pp. 47–60.

loam 2 to 4 feet in thickness, and this has probably concealed many bowlders which would otherwise have been exposed on the surface of the till. The number of bowlders on the surface is less than on the plains between this morainic system and the Cerro Gordo moraine. The sheet of loam is apparently distinct in origin from the sheet of till which underlies it, but no evidence was discovered that it was separated from it by a wide time interval. This silt is distinct from the main loess deposit of western and southern Illinois, since the latter preceded the Shelbyville moraine in its date of deposition. The origin of surface silts of this class, like that of the great loess deposits, is problematical.

A buried soil is frequently found beneath the ridges of this morainic system, but it appears to be at a lower horizon than the base of the drift deposited in connection with these moraines. Its horizon is probably at the junction of the Shelbyville drift sheet with the underlying older drift. Professor Rolfe, of the Illinois State University, has collected records of many wells in southern Champaign County, between Urbana and Tolono, in which a buried soil is found at a depth of 60 to 100 feet. These records have not as yet been published by him. When found beneath the plains the depth to the soil is less than when beneath the drift ridges. On the ridge in the vicinity of Tolono it is struck at about 100 feet and it is found at nearly as great depth on the ridge near Urbana, while on intervening plains the depth is but 60 to 75 feet. Instances of buried muck reported from Vermilion County, Indiana, by F. H. Bradley[1] occur beneath the gravel of the Wabash terraces. Wells were sunk through about 60 feet of alluvial sand, and then encountered 6 to 10 feet of soft, sticky bluish mud filled with leaves, twigs, and trunks of trees. In Fountain County, Indiana, between the main morainic belt and the Inner Ridge, there is a plain in which a black muck has been struck below the till at depths of 25 to 50 feet. Although the depth is much less than in Champaign County, Illinois, the soil is thought to be at the same horizon, namely, the junction of the Shelbyville drift sheet with the underlying older drift.

The detailed discussion of well sections which follows begins at the west end of the morainic system in Piatt County and passes eastward, and serves to illustrate variations in the structure from point to point. There are, unfortunately, but few reliable records obtained.

[1] Geol. of Indiana, 1869, p. 140.

A well on the farm of Mrs. Robert Carson, in eastern Piatt County, near the south border of the moraine, reached a depth of 200 feet without encountering rock. It appears to have been mainly through a fine sand. On the north border of Blue Ridge Frank Delaney sunk a well to a depth of 280 feet without encountering rock. A well was sunk by George Frankenburgher on the crest of the moraine, 2 miles east of Mahomet, to a depth of about 200 feet without encountering rock. It was almost entirely through till.

An experimental boring for gas, oil, etc., made at the city of Champaign in the winter of 1891–92, is reported by E. M. Burr, of Champaign, to have the following drift section:

Section of boring at Champaign, Illinois.

	Feet.
Black soil and a pebbleless clay subsoil	4
Yellow and gray pebbly clay	44
Quicksand	12
Gravel	7
Gray pebbly clay	35
Quicksand	71
Water-bearing gravel	6
Hardpan (exact nature not noted)	5
Quicksand	11
Gravel	7
Hard, pebbly clay	51
Clay containing small pieces of coal	1
Quicksand and gravel	21
Gray clay containing pieces of coal near bottom	9
Quicksand	16
Total drift	300

The following section of an attempted coal shaft sunk by John Faulds at Champaign appears in the Geology of Illinois (Vol. IV., p. 272):

Section of coal shaft at Champaign, Illinois.

	Feet.
Soil, clay, and quicksand	17
Red and blue clay	73
Peat	2
Quicksand, with tree 7 inches in diameter	9
Soft yellow clay	9
Sand	3
Yellow clay	7
Sand and gravel	59
Total depth	179

The bottom of the drift was not reached in this place. The statement is made that an earlier boring near by, of which a complete record was not

accessible, is said to have reached a blue shale at 168 feet. This supposed shale may, however, prove to be hard blue till.

A boring made in Urbana in 1884, about a half mile east of the roundhouse of the Cleveland, Cincinnati, Chicago and St. Louis Railway, has the following section, as reported by Prof. C. W. Rolfe:

Section of boring at Urbana, Illinois.

	Feet.
Soil	1
Yellow clay containing few pebbles	12
Blue clay containing few pebbles	13
Very stony clay	32
Coarse sand and gravel	14
Black soil	2
Water-bearing yellow sand	16
Blue clay	1
Quicksand	4½
Blue clay	1
Quicksand	3
Blue bowlder clay	16
Quicksand	35
Blue bowlder clay	18
Sand and gravel	17
Quicksand	69
Gravelly sand	9
Total drift	265

The altitude of the well mouths, both in the Champaign and in the Urbana borings, is about 750 feet above tide. Within $1\frac{1}{4}$ miles east of the court-house in Urbana, at a level but a little lower than the well just recorded, rock is struck within 100 feet of the surface. On a line eastward from that point to the Wabash Valley, in Indiana, the drift seldom exceeds 100 feet in thickness.

A well at Thomas Goody's, in Philo, on the crest of the moraine, attained a depth of 171 feet without reaching rock, and penetrated the following drift beds:

Section of well at Philo, Illinois.

	Feet.
Pebbly clay changing from brown to blue	20
Pebbly blue clay	75
Pebbly blue clay, interbedded with dry sand in thin beds	30–35
Sandy clay called hardpan	4
Fine yellow sand, water bearing	36
Total	171

A well on the moraine 2 miles south of Philo, in process of boring at the time of my visit, penetrated 110 feet of till, mainly of blue color, and

apparently referable to the Shelbyville and later sheets. Beneath this depth alternating beds of sand and clay of blue color continued 46 feet to the bottom of the well. Several other wells have been made along the moraine in this county whose depths exceed 100 feet. As a rule they pass through a thick bed of till before striking water-bearing sand or gravel. A similar sheet of till is passed through on the plain between the middle and outer ridges in southern Champaign County and on the inner ridge and bordering plains in eastern Champaign County. A boring at Sidney on a plain north of the inner ridge, made in 1884 by the Sidney Mineral Company, penetrated but 95 feet of drift, as follows:[1]

Section of drift in a boring at Sidney, Illinois.

	Feet.
Yellow clay, containing few pebbles	17
Blue clay, containing few pebbles	18
Pebbly blue clay	5
Pebbly yellow clay	15
Sand and gravel	5
Pebbly clay	35
Total drift	95

In northeast Douglas County, and thence eastward along the moraine, wells are usually but 30 to 40 feet in depth and very rarely reach a depth of 100 feet. They are mainly through till, except in southeastern Vermilion County, where in some cases considerable gravel is penetrated.

A well on the north face of the Inner Ridge, a short distance east of the State line, at the residence of Mr. Malone, did not reach the bottom of the drift at a depth of 241 feet, and failed to obtain water. The well mouth has an altitude about 625 feet above tide, or 160 feet above the Wabash River. The following section was furnished by Mr. Malone:

Section of Malone's well near Eugene, Indiana.

	Feet.
Pebbly yellow clay	15
Pebbly blue clay	35
Dry sand and gravel	10
Hard pebbly gray clay (probably Illinoian)	55
Alternations of clay with sand and gravel in thin beds	125
Total depth	240

F. H. Bradley has published the following section of drift exposed on a branch of Johnson's Creek, near Newport, Indiana:[2]

[1] For this section I am indebted to Prof. C. W. Rolfe.

[2] Geology of Indiana, 1869, p. 141.

Section of drift near Newport, Indiana.

	Feet.	In.
Bowlder clay, with pebbles of Silurian limestone and trap	30	0
Yellow clay, with fragments of coal, shale, sandstone, etc	0	4
Bowlder clay, with pebbles of Silurian limestone	25	0
Ferruginous sand	Streak.	
Bowlder clay, from the northwest, with pebbles of various metamorphic rocks and trap, and nuggets of native copper	50	0
Total exposure	105	4

East of the Wabash, in Parke County, wells along the outer or main belt and on the plain north of it are seldom more than 30 feet in depth. They pass through about 15 feet of yellow till, beneath which some of them enter blue till, while others enter gravel. Thin beds of sand or gravel are often found associated with the yellow as well as the blue till.

Wells in western Montgomery County are in some cases sunk to a depth of 50 or 75 feet, mainly through blue till. On the plain in Fountain County, and also on the inner morainic ridge, wells seldom reach a depth of 50 feet, and usually obtain water without entering rock, there being beds of water-bearing sand or gravel associated with the till sheet.

CHARACTER OF OUTWASH.

As a rule the plains outside the ridges of this morainic system show scarcely any sand or gravel outwash from the moraine, and there appears to have been only a gentle movement of waters from the ice margin southward down the valleys.

At the point where the Sangamon River emerges from the moraine in the village of Mahomet there is a gravelly outwash having a depth of 6 or 7 feet, which caps the till plain on the immediate border of the valley. Exposures are to be seen east of the railway station and also at several points in the village. The exposures east of the railway station show a bed of loess-like silt about 3 feet in thickness immediately below the gravel, and beneath this a brownish-yellow till. The loess-like silt is similar to that which covers the plains quite extensively in this region. The gravel overwash is of very limited extent, reaching out scarcely a half mile from the south border of the moraine. It merges into low gravelly knolls on the border of the moraine. These features seem to leave no question of the gravel being derived from the ice sheet during the formation of the moraine. Attention has already been called to a gravelly tract along the Sangamon

River below this point. The small amount of outwash shown at the border of the moraine seems to make it doubtful if the gravel belt along the river was chiefly formed as morainic outwash. The gravel may be largely a residue from the cutting down of the sheet of drift outside the moraine.

Kaskaskia and Embarras valleys have, as a rule, either silt or till banks where they border the ridges of this morainic system. It is probable that the ice sheet had feeble outwash at these valleys, as they are favorably situated for receiving any outwash which may have been contributed from the moraine, the course of the Kaskaskia being for several miles but a short distance outside the Outer Ridge and the course of the Embarras being for an even greater distance just outside the Middle Ridge.

Near the head of Bruillett's Creek, in northern Edgar County, the plain outside the moraine has an area of several square miles which is underlain by gravel. Tributaries of Bruillett's Creek lead down from the moraine into this plain and lose their waters in its gravel. In some cases these streams do not maintain a channel in this plain. It is not entirely certain that this gravel is an outwash from the moraine, since the moraine itself is of a stiff clayey constitution on the immediate borders of the gravelly plain. If the moraine had a gravelly constitution on this border, as it does at Mahomet, the case would seem more certain.

Along the Wabash River Valley extensive gravel terraces occur both above and below the points where the ridges of this morainic system cross. Possibly a portion of the gravel connects with this morainic system, but by far the larger part connects with moraines of later date which cross farther up the valley.

Near Bloomingdale, Indiana, a gravel-filled valley not now occupied by a stream leads southward from the moraine across Leatherwood Creek to the valley of Rocky Run, a distance of 2 miles, and thence continues down Rocky Run to the Wabash Valley. The portion not occupied by a stream is bordered by bluffs 30 to 50 feet in height, and has a width of from one-third to one-half mile. The relation of this valley to the Champaign morainic system is not definitely settled. It is perhaps an interglacial valley, whose upper course has been overridden and concealed by the Champaign drift sheet. The gravel filling in its bottom may prove to be an outwash from the moraine, though this is not entirely certain. It is not evident why Leatherwood Creek chose a passage westward instead of turn-

ing down this valley. Its flood plain is now only about 20 feet below the level of the bottom of the abandoned valley at the point where it crosses it, and the difficulties of opening a westward passage seem greater than would be necessary to have adopted the course of the abandoned valley.

On the outer border of the Inner Ridge in Shawnee Township, Fountain County, Indiana, just north of the point where Coal Creek is deflected southward by the morainic ridge, there is a small plain underlain with gravel which is perhaps an overwash from the moraine. There is also considerable gravel along Coal Creek below the bend, preserved in terrace-like remnants standing 35 to 50 feet above the present stream. It is not determined, however, whether this gravel is an outwash from the drift ridge or is merely a residue formed in the cutting of the valley. Against the latter view it may be said that the present stream seems scarcely adequate to transport gravel deposits of such coarseness as are here displayed.

Sugar Creek Valley carries gravel terraces in its lower course, but these terraces are as well developed in portions of the valley above the crossing of this morainic system as below that point. The lower course of the creek is on the inner border of the Outer Ridge of this morainic system, and thus is very unfavorably situated for receiving an outwash. Furthermore, the gravel terraces seem to be built up in a valley which had been excavated in the Champaign drift sheet. It is highly probable, therefore, that these gravel terraces have no connection with the Champaign morainic system, but are of later date.

ASSOCIATED TILL PLAINS.

Between the ridges of this morainic system there are, as already noted, till plains ranging in width from 1 or 2 up to about 10 miles in the Illinois portion, and reaching a width of nearly 20 miles in Parke and Fountain counties, Indiana. On these plains there are occasional low knolls, but the general surface is much smoother than that of the bordering morainic ridges.

Another plain having greater extent occupies the interval between the Inner Ridge of the Champaign morainic system and the Outer Ridge of the Bloomington morainic system. Its width at the northwest, near the corners of Ford, McLean, and Champaign counties, is about 15 miles, and this width is maintained across Champaign County. In Vermilion County,

Illinois, it decreases to 10 or 12 miles, and continues into Indiana with about the same width. On this plain, as on the plains between the ridges of the Champaign morainic system, the surface is generally much smoother than on the ridges. There are occasional knolls, however, which reach a height of 30 feet or more, and swells 5 to 10 feet in height are found in nearly every township.

The thickness of drift differs from that in the morainic ridges only by the measure of the relief of the ridges. In the Indiana portion, and for some distance westward into Illinois, rock is often encountered at a depth of 50 feet or less, but in Champaign County the drift thickness increases to 200 feet or more, for the thickness, as on the ridges, is much greater in the western than in the eastern portion of the county. The thick drift continues northwestward into Ford and McLean counties.

There is beneath these plains a buried soil found at a depth of 75 to 100 feet or less in Champaign County, and at 25 to 50 feet in counties farther east. This appears to be at the base of the Shelbyville drift sheet. As yet no soil has been discovered between the Champaign and Shelbyville sheets. The drift appears to be composed more largely of till beneath these plains than in the moraines, but sufficient gravel and sand occur to afford water for wells throughout most of the region.

SECTION III. BLOOMINGTON MORAINIC SYSTEM.

The system of moraines to which the name Bloomington is applied is scarcely surpassed in strength of development or in complexity of features by any other morainic system in the early Wisconsin series. It is one of the most important in the series, not only because of its strength of development but because it extends in places beyond the earlier moraines of the series, and for a distance of about 120 miles constitutes the border of the Wisconsin drift. It receives its name from the city of Bloomington, Illinois, which stands on a prominent portion of its chief ridge. The name seems especially pertinent since Bloomington is situated near the middle point of this morainic loop, just as Shelbyville is situated near the middle point of the Shelbyville loop.

Where best developed there are two bulky ridges, constituting the outer part of the system, and two smaller ridges constituting the inner part. The four ridges are not continuously developed, however, since they inter-

lock in places, and the weaker ridges fade out at intervals. In places each of the bulky ridges are double crested and more or less distinctly separable, making four ridges aside from the two weaker ones. The system may be traced satisfactorily for a distance of about 300 miles from the northern tier of counties in Illinois around to the western tier in Indiana. In northern Illinois this system becomes so closely associated with other systems in a composite belt that further tracing seems impracticable. This northern portion from Peoria County northward overrides or becomes united with the Shelbyville morainic system, so that the latter is no longer traceable. In western Indiana the Bloomington system is overridden by moraines of late Wisconsin date, which have partially concealed its further course.

DISTRIBUTION.

The Bloomington morainic system (carrying with it perhaps the Shelbyville system) separates from the composite belt of moraines in northern Kane County and passes in a course slightly south of west across central Dekalb County, occupying a space about 12 or 14 miles in width. Its outer and inner borders are each characterized by a definite ridge. On the borders of Dekalb and Lee counties, in the vicinity of Shabbona and Pawpaw, it becomes narrowed to only 6 miles, owing to a reentrant angle on the outer border. Thus far the weak inner members of the system are undeveloped. Continuing southwestward it expands in northern Bureau County to a width of 18 or 20 miles. This does not include a weak inner member of the system which sets in near Earlville and leads southward along a line several miles east of the inner border of the main ridges, and whose course is discussed below. The ridge along the inner border dies out in eastern Bureau County, so that upon approaching the Illinois River in southern Bureau County only the ridge on the outer border of the system is maintained in strength. The ridge which dies out in eastern Bureau County apparently finds continuation in a ridge that crosses northern McLean County, as noted below. The bulky ridge passes southward through western Marshall and northeastern Peoria counties and occupies a width of several miles. The portion in northeastern Peoria County is well shown in the Dunlap topographic sheet, where it forms the divide between Kickapoo Creek and smaller tributaries of the Illinois that flow eastward into the river. The Shelbyville moraine emerges from beneath it in eastern Stark

County, as previously noted. This feature also may be seen on the Dunlap sheet, the point of emergence being near Lawn Ridge. The Bloomington ridge crosses the Illinois River just above the city of Peoria and passes southeastward across northern Tazewell County with an elevated semimorainic tract on its eastern border, extending into western Woodford County. In northwestern McLean County, immediately east of the Mackinaw River, two prominent ridges are found in place of the one ridge farther west. They are closely associated and lead across the county in a curving course bearing south of east in the western portion and north of east in the eastern portion. The ridges are more closely associated in the eastern than in the western portion of the county, but nowhere occupy a belt more than 10 miles in width. In the eastern portion the width is not more than 6 miles. The plane tract between them is only 1 or 2 miles in width. In Ford County a slight reentrant angle is formed immediately north of Gibson, and the morainic system which bears northeastward in the western part of the county changes abruptly to a southeastward course in the central portion. The inner border of the reentrant portion extends northward as far as Chatsworth and Piper. From this reentrant angle the outer border leads from Gibson southeastward across northeastern Champaign County, passing near Rantoul and Gifford, and enters Vermilion County about 3 miles northwest of Fithian. Its course is thence directly eastward across the county into Indiana, passing a couple of miles north of Danville, Illinois. It is very clearly defined on the Danville topographic sheet. In Warren County, Indiana, its course changes to north of east, following nearly the north bluff of Wabash River to Pine Creek Valley, near Williamsport. The moraine here swings northward and is traceable as far as eastern Benton County, where it dies away in a gently undulating plain. This system is overridden by a series of weak bowldery moraines of the late Wisconsin series in northern Warren and southern Benton counties, but is not greatly obscured along the line of the outer belts. Greater obliteration apparently occurred a few miles back from the late Wisconsin border. However, the Bloomington system apparently finds its continuation in a belt of very thick drift which leads from Benton County, Indiana, southeastward across Tippecanoe, Clinton, Boone, and Hamilton counties, and thence eastward into Ohio. But this belt is outside the territory embraced in the present report.

Returning to the reentrant angle in Ford County, Illinois, the inner border of the Bloomington system is found to pass southward from Piper,

near Thawville and Loda, and thence to swing eastward in a curving course through eastern Ford, northern Vermilion, and southeastern Iroquois counties. The inner bulky ridge of the system continues eastward to Fowler, Indiana, where it terminates very abruptly a few miles west of the outer ridge.

From the reentrant angle in Ford County two weak ridges are traceable westward. The inner or Chatsworth-Cayuga Ridge leads from Chatsworth north of west to Cayuga, where for a few miles it passes beneath, or is nearly obscured by, the Marseilles moraine. Near Blackstone, in northern Livingston County, a ridge which is probably its continuation emerges from beneath that moraine and passes northwestward nearly parallel with the Vermilion River through or near Kernan, Grand Ridge, and Farm Ridge villages to the Illinois Valley at Utica. For a part of the course it forms the divide between the Illinois and Vermilion rivers and may easily be traced on the Ottawa and Lasalle topographic sheets. This northern part is known as Grand or Farm Ridge. North from the Illinois its course is slightly east of north from Utica past Earlville, where it fades out near the inner margin of the main moraine in southern Dekalb County. It is well shown in the east part of the Lasalle sheet and northwest part of the Ottawa sheet. The gaps in this ridge are narrow, and are discussed below (p. 259). This ridge probably finds its correlative east of the Ford County reentrant angle in a belt of undulating or slightly ridged drift leading eastward across central Iroquois County. The latter belt, however, scarcely constitutes a definite moraine, being distinctly ridged only for a few miles along the north border of Sugar Creek east from Milford. It disappears beneath a moraine of late Wisconsin age near the State line south of Sheldon, Illinois.

The other ridge which leads west from the Ford County reentrant angle, commonly known as Cropsey Ridge, from a village situated on it, is distinctly traceable across the northern part of McLean County, where it constitutes the water parting between Mackinaw and Vermilion rivers. It fades out in the vicinity of Gridley, and is not definitely developed toward the west or north until the Illinois Valley is passed. It seems, however, to be a continuation of the belt which fades out in eastern Bureau County, as noted above. The character of the topography in the interval between these ridges is discussed below (p. 281).

RELIEF.

The relief on the outer border seldom falls below 50 feet and in places approaches 200 feet. The average relief is probably 75 or 100 feet. The least relief is found in portions of Ford and Champaign counties, Illinois, where it is about 50 feet. The greatest relief is found in southern Lee and northern Bureau counties, where the moraine is bordered on the west by the Green River Basin. The moraine here has an altitude of 900 to 1,000 feet or more above tide, while the basin on the immediate borders of the moraine rises from scarcely 700 feet at the west to about 850 feet at the east, thus giving the moraine a relief of 150 to 200 feet.

Between the ridges of this system there is very little depression in Dekalb and Lee counties. But on the inner border of the system in these counties there is nearly as pronounced relief as on the outer border. Indeed, in places it exceeds that on the outer border, and probably it averages 100 feet. The relief on the inner border continues prominent southwestward into Bureau County, but falls off rapidly in that county, becoming scarcely perceptible in the vicinity of the Illinois River. The outer ridge, however, maintains its great relief throughout Bureau County and rises 100 feet or more above the plain and lower ridge on its inner border in the eastern part of the county. In southern Bureau, western Marshall, and northeastern Peoria counties it stands 150 feet or more above the narrow upland between it and the Illinois Valley. This prominent ridge probably includes both the Shelbyville and Bloomington systems, for the former separates from it in eastern Stark county, as noted above. Upon crossing the Illinois into Woodford County the uplands on the inner border of the Bloomington moraine are found to stand but a few feet lower than the crest, and eastward from this county there is generally a very gradual descent on the inner border of the main ridges, a descent seldom exceeding 25 or 30 feet to the mile.

The small ridge which leads across northern McLean County has a relief of but 30 to 50 feet on its outer border and a gradual descent on its inner border. The ridge leading northwestward from Chatsworth to Earlville usually rises 30 to 50 feet above the outer border, but reaches about 75 feet in places in central Lasalle County. The relief on the inner border is nearly as great as on the outer, but is usually more gradual

RANGE IN ALTITUDE.

This morainic system presents a range in altitude of only about 300 feet, its highest points being slightly more than 1,000 feet above tide, while few points, aside from valleys, fall below 700 feet. The range, both along the crest and along the immediate outer border, is set forth by counties in the following table:

Table showing range in altitude of the Bloomington morainic system.

County.	Crest, above tide.	Outer border, above tide.
	Feet.	*Feet.*
Dekalb (Illinois)	875- 975	775-850
Ogle (Illinois)	875- 940	790-820
Lee (Illinois)	900-1,025	740-860
Bureau (Illinois)	700- 989	675-825
Marshall (Illinois)	800- 900	700-800
Peoria (Illinois)	700- 830	650-775
Tazewell (Illinois)	700- 825	650-725
McLean (Illinois)	775- 913	700-820
Ford (Illinois)	775- 860	740-760
Champaign (Illinois)	750- 830	700-760
Vermilion (Illinois)	680- 790	630-700
Warren (Indiana)	700- 775	625-675
Benton (Indiana)	750- 825	675-725

SURFACE CONTOURS.

A general statement can scarcely be made which will set forth the variations in contour or topographic expression of this morainic system throughout its entire length. It is found convenient to discuss it in sections, beginning at the north and proceeding southward. The first section embraces the portion between western Kane County, where this system separates from the morainic complex of northern Illinois, and the head of Bureau Creek in northeastern Lee County, a section 35 or 40 miles in length. The second section (about 50 miles) embraces the portion drained by Bureau Creek and its tributaries. The third section (40 miles) embraces the portion along the west side of the Illinois in Bureau, Marshall, and Peoria counties. The fourth section (20 miles) embraces the portion

between the Illinois and Mackinaw rivers in Tazewell and Woodford counties. The fifth section (50 to 55 miles) embraces the portion between the Mackinaw River and the reentrant angle in Ford County. The sixth section (nearly 100 miles) embraces the portion between the reentrant angle in Ford County, Illinois, and points where this system passes beneath the moraines of late Wisconsin age in Benton and Warren counties, Indiana. For the distribution of the several sections see Pl. VI.

Between western Kane County and the head of Bureau Creek.—The section between western Kane County, Illinois, and the head of Bureau Creek, taken as a whole, consists of a mass of drift standing 50 to 100 feet or more above the plains on the northwest and southeast borders, and occupying a width of 6 to 15 miles. Much of the surface is nearly plane, and differs but little from that of the plain on the southeast. There is, however, scarcely a square mile in which knolls 10 to 20 feet high are not present, and also shallow basins which contain ponds. The decidedly morainic expression is confined to three somewhat narrow belts, one on the outer border, another on the inner border, and an intermediate less definite belt

The belt on the outer border leads from Hampshire westward into Dekalb County, crossing South Kishwaukee River just above the bend near Genoa, and then curves around to the southwest and south in western Dekalb and southeastern Ogle and eastern Lee counties. Its width is seldom more than 3 miles, and in places scarcely reaches 2 miles. From Hampshire west to the Kishwaukee River it is less prominently ridged than west of that stream, there being a rise of scarcely 50 feet to its highest points from the plain on the north. This portion, however, has about as much morainic expression as the higher part of the border to the west. Knolls 10 to 25 feet are closely aggregated and inclose shallow basins. The basins are usually depressed but 5 or 6 feet below the lowest part of their rims, and occupy only an acre or two. Occasionally a basin occupying as much as 10 acres is to be seen. From South Kishwaukee River southwestward through western Dekalb and southeastern Ogle counties, the outer belt consists of a series of narrow ridges with shallow sags between them, each trending with the entire belt in a NE.–SW. course, changing to southward in Ogle County. The ridges are each a mile or less in width and stand 30 to 50 feet above the intervening sags. There are in places four ridges, but usually only two or three. Each ridge has gentle undulations on its crest and slope, seldom

more than 10 or 15 feet high. This breaking up of a morainic belt into several ridges at a salient curve is a common feature in this and other morainic systems. In Ogle and northeastern Lee counties sloughs are a conspicuous feature among the knolls. This outer belt is interrupted by several gaps, occupied by streams, which head on its inner border and pass through it to the lower outlying districts. Named in order from east to west there are the following: Coon Creek, South Kishwaukee River, Owen's Creek, Killbuck Creek, Kite River, and two branches of Willow Creek. The crest of the morainic belt is absent for a mile or more at each of these valleys. Apparently there were gaps of this width in it prior to the opening of the drainage lines, for the slopes bordering the valleys carry knolls and shallow basins such as characterize slightly eroded portions of the belt. As shown below, these gaps were probably formed by streams issuing from the ice sheet. The valley bottoms range in width from 60 rods up to fully one-half mile, the broadest being at Kishwaukee River.

The middle belt appears in western Kane County at Burlington. A morainic spur is found to lead southwestward from the inner border of the outer belt into eastern Dekalb County, and to fade away 2 miles east of Sycamore. It is about 1 mile in width, and is characterized by numerous basins and low knolls, which give it fully as strong expression as the neighboring portion of the outer belt, from which it is separated by a narrow plain 1½ or 2 miles in width. There is also a basement ridge with a relief of perhaps 20 feet. For several miles west from the points where the Burlington spur dies out, knolls 10 to 25 feet high are rather numerous and constitute a probable line of continuation. Near Malta a definite ridge appears, which leads southwestward to the outer belt in the southwest corner of Malta Township, Dekalb County, and thence southward along the east border of the outer belt, through western Milan and northwestern Shabbona townships, passing just east of the village of Lee. For 3 or 4 miles in western Milan Township it is combined with the outer belt, but elsewhere it is separated from it by a narrow plane tract about a mile in average width. In western Shabbona Township, Dekalb County, it becomes completely united with the outer belt. This ridge, like the Burlington spur, is about a mile in average width. It has a relief of 20 to 40 feet above the bordering plane tracts. Its surface is gently undulating, but basins are rare, except where it is closely associated with the outer belt in Milan Township. The

altitude of the ridge just discussed is about as great as that of the outer belt, and it constitutes the source of several of the streams which lead through the outer belt, viz, Owen's Creek, Killbuck Creek, Kite River, and Willow Creek.

By returning again to western Kane County, to Elburn, where the inner member leaves the composite belt, and tracing the moraine westward, it is found to take a more direct course than the outer one. It leads nearly due west for about 10 miles, being throughout much of the distance between Elburn and Cortland in view from the Chicago and Northwestern Railway. Immediately south of Cortland it changes to a southwestward trend and joins the outer belt for a few miles in southwestern Shabbona Township, Dekalb County, and eastern Wyoming Township, Lee County, at the southwestern limits of the section of the morainic system under discussion. Throughout much of this distance it has a well-defined crest and occupies a width of 1 to 2 miles. For a few miles at the curving portion southwest of Cortland it presents two ridges separated by a sag or plane tract about a mile in width that stands 20 to 30 feet below the level of the crests of the ridges. In western Kane County several sharp gravel knolls 30 to 40 feet in height are found in this belt, and occasionally sharp knolls are found in it farther west. As a rule, however, its undulations are gentle. The crest stands only 20 to 40 feet above the district to the north, but there is a descent of nearly 100 feet within a couple of miles on the south border. On the slope there are low knolls and a gently undulating surface. At its junction with the outer border belt in Shabbona and Wyoming townships numerous basins and sharp knolls occur. The knolls are in some cases 30 or 40 feet in height, though usually 20 feet or less. This inner moraine forms the divide between South Kishwaukee River and several tributaries of Fox River, and is not crossed by any stream east of its junction with the outer belt. Near the point of junction south of Shabbona it is crossed by Indian Creek, a tributary of Fox River, which heads in the combined belt and flows southwestward. In its course through this moraine the creek winds about greatly among the knolls and has not so broad a passage as is afforded the streams which lead northward across the outer belt.

In the Bureau Creek drainage basin.—The second section of the Bloomington morainic system, which embraces the drainage basin of Bureau Creek, maintains a belt on its outer border fully as prominent as that of the

section just discussed, but its inner-border belt, as noted above, loses its strength in eastern Bureau County, and in the vicinity of the Illinois River rises only a few feet above the inner-border plain. With the decline of this belt a still later belt appears on the plain to the east, as noted above. The two main belts are closely associated for about 20 miles in southern Lee County, being separated only by a narrow plain 1 to 2 miles in width, through the midst of which Bureau Creek has its passage. They then diverge, the course of the inner one being slightly west of south, through eastern Bureau County, while the outer continues with a course slightly south of west along the borders of Lee and Bureau counties for a distance of 20 miles. It there turns southward through central Bureau County, curving around the western border of the Bureau Creek Basin and passing just west of Wyanet and Tiskilwa. The plain between the moraines in Bureau County has a gently undulating surface and stands nearly as high as the inner moraine, but is much lower than the outer one. There is, in this plain, a slight tendency to ridging, with NE.–SW. trend, which to some extent governs the course of streams.

The outer belt throughout its course in southern Lee and northern and central Bureau counties maintains a width of 4 to 6 miles. This includes gradual slopes which culminate in a well-defined narrow-crested ridge that is developed along a considerable portion of the section under discussion. The crested ridge usually occupies a breadth of less than a mile, and stands 30 to 50 feet above the less sharply ridged portions on its borders. In places the sharp crest is absent and the gradual slopes occupy its entire breadth. Near Wyanet a narrow depression as low as the outer-border plain interrupts this ridge and furnishes a passage for the Hennepin Canal, now under construction. This depression is not an open valley, but has morainic knolls on its bottom and slopes.

In southern Lee County the knolls and undulations on the slopes of the moraine are much less conspicuous than in Bureau County, their height usually being but 10 or 20 feet, while in Bureau County they frequently attain a height of 30 or 40 feet. Basins are common only in central Bureau County, though they are found occasionally in other parts of the moraines. The deepest are only 10 or 15 feet below the bordering rims, and their area is seldom more than an acre or so each. On the outer face of the moraine in Lee County, from the vicinity of the Third Principal

Meridian westward to northern Bureau County, there are numerous sand knolls and ridges, 10 to 40 feet in height, which add greatly to the inequalities of the surface. These sand accumulations follow the lines of ridges or knolls in the moraine, rather than the depressions between them. The sand is still subject to slight modification by wind action, and its ridges, as well as its presence on the moraine, are probably the result of wind transportation from the Green River Basin, which borders this portion of the moraine on the west.

The inner belt of this system, as noted above, is merged with the outer from the vicinity of Shabbona southwestward to Pawpaw, and presents a knob-and-basin topography along the line of junction. Upon separating from the outer belt the topography changes to gentle undulations, and there is also a tendency to ridging in the line of the belt. In places a cross section would lead over at least three nearly parallel ridges separated by narrow sags, the whole series occupying a width of scarcely 2 miles. The ridges are, however, not distinctly maintained for long distances, but are at intervals crowded together. These ridges are of about equal height and rise only 25 to 50 feet above the plain on their outer border. The relief on the inner or southeast border is nearly 150 feet in eastern Lee County, and this great relief is maintained for 10 or 12 miles southwestward in southeastern Lee and northwestern Lasalle counties. Upon entering Bureau County the relief decreases rapidly, as already noted, but the expression continues as strong as in the portion having greater relief. Knolls 20 feet or more in height are closely aggregated, and are disposed in chains trending in line with the belt. Upon approaching the Illinois Valley they become more scattering, and the belt fades out about 2 miles north of Depue. The feebly developed portion of this belt is shown in the northwest corner of the Lasalle topographic sheet and in the eastern part of the Hennepin sheet between East Bureau and Brush creeks. The ridge which leads southward from Earlville past Utica, a few miles east of this moraine, is discussed farther on, as is also the topography in the line of continuation of this moraine in Putnam, Marshall, Woodford, and McLean counties. (See pp. 261, 281.)

In Bureau, Marshall, and Peoria counties.—The third section of the Bloomington morainic system embraces the portion of the moraine west of the Illinois River in Bureau, Marshall, and Peoria counties. This consists mainly of a large ridge, 4 to 6 miles in width and 100 feet or more in height above

the districts on the west and an even greater height above the narrow plain between the ridge and the river bluff. Aside from this main ridge there are minor ridges trending parallel with it on its inner or eastern border. These minor ridges are a mile or less in width, 25 to 50 feet in height, and are maintained for only a few miles in a place. The surfaces are much smoother than that of the main ridge. They are similar to the slight ridgings found between the inner and outer belts in eastern Bureau County, and, like those ridges, have an influence on the course of drainage. One of the most conspicuous instances of the governing of drainage is that of Senachwine Creek, in southwestern Marshall County, which owes its southward course to a low drift ridge on its east border.

The main ridge has a topography similar to that of its northern continuation in central and northern Bureau County. In places a sharply outlined crest is developed, but usually the higher part of the ridge is broken up into knolls and sharp disjointed ridges which rise 20 to 40 feet above neighboring basins or sags. Shallow basins are a common feature along this portion of the moraine. On the outer face the border is irregular, being indented by valley-like extensions of the outer-border plain, which in some cases reach a mile or more back into the moraine. Between these indentations there are spur-like projections. The moraine is nowhere cut through by any of these low tracts, though a line along its crest occasionally oscillates 100 feet or more within a space of 2 or 3 miles. On the whole, this section is scarcely surpassed in strength by any other portion of this morainic system.

Between the Illinois and Mackinaw rivers.—The section embraced between the Illinois and Mackinaw rivers has a well-defined outer or southwest border, but its inner or northeast border is difficult to determine. It merges on the northeast into an elevated tract with a gently undulating surface, whose general altitude is about as great as that of the portion of the belt which presents stronger morainic expression. This elevated tract extends as far east as Cazenovia. Should the entire district between Cazenovia and the outer border be included in the moraine, it would have a breadth of about 14 miles, or more than twice the breadth of the bulky outer ridge formed on the west side of the river. The strongly morainic expression is confined, however, to the outer or southwest face in a belt only 3 or 4 miles in width. This face presents a series of drift billows 20 to 30 feet in height,

among which are sags and shallow basins. The swells are usually closely aggregated, but in places nearly plane tracts of a square mile or more appear in the midst of this belt. An instance of such a plane tract may be seen south of Deer Creek village. The elevated tract on the northeast border of this moraine has only occasional low swells 10 or 15 feet in height, the greater part of the surface being as smooth as the plains farther north and east, and differing from them only 50 to 75 feet in altitude. The descent is made in a distance of 2 or 3 miles, and is therefore so gradual as to be scarcely perceptible to the eye. The relief on the outer border is more conspicuous than on the inner, a rise of 100 feet being made in about 2 miles at the prominent parts of the moraine. This border is also made conspicuous by the change from the very flat surface outside the moraine to the billowy surface presented by its outer face.

Between Mackinaw River and the Ford County reentrant.—East of the Mackinaw River, near the borders of Woodford, McLean, and Tazewell counties, the Bloomington morainic system presents two well-defined bulky ridges which are separated by a narrow plain or sag 1 or 2 miles or more in width. These ridges are distinctly maintained from the extreme northwest corner of McLean County eastward to Padua, a distance of nearly 30 miles, beyond which, for 20 to 25 miles, to the Ford County reentrant, they are combined into a single belt.

The inner ridge enters McLean County from Woodford County near the line of the third principal meridian and passes southeastward through Normal and thence eastward through Barnes to Padua, where it becomes combined with the outer ridge. It has a general width of 2 or 3 miles and rises 30 to 50 feet above the sag or plain on its south border. The surface is billowy, with oscillations of 20 or 30 feet between the higher swells and neighboring sags. Many smaller swells occur, with a height of 5 or 10 feet. The slope of these swells is usually gentle, and knolls 20 feet in height occupy several acres. In places this moraine presents a sharply outlined crest; a conspicuous instance was noted northwest of Padua, where a ridge-like crest with a width of only one-fourth to one-half mile stands about 50 feet above the tracts on either side. As a rule, however, the higher portion of this belt consists of a series of swells similar to those found on the slopes. For several miles north from this inner ridge the surface is

gently undulating and dotted with occasional knolls of considerable prominence, the highest knolls rising 30 to 40 feet above border districts.

The outer ridge crosses Mackinaw River immediately above Mackinaw village and leads southeastward to Bloomington and thence eastward to its point of junction with the inner ridge near Padua. It has a breadth of about 3 miles. It is crossed by several streams which head in the inner ridge, among which are three of the headwater branches of Sugar Creek, two headwater branches of Kickapoo Creek, and one headwater branch of Salt Creek. Sangamon River also leads through it, east from the junction with the inner ridge. There are thus seven streams crossing it within a space of 35 or 40 miles, admitting only about 5 miles average distance between streams. The gaps through which these streams pass, each cause a break in the crest of the moraine nearly a mile in width. They do not appear to be entirely erosion gaps, for the morainic swells occupy them down nearly to the level of the streams, or about 75 to 100 feet below the level of the neighboring crests. It is probable that streams issuing from the ice sheet at the time the moraine was forming prevented the accumulation of heavy deposits in the vicinity of their points of departure from the ice. Between these gaps the moraine usually has a well-defined crest and gently undulating surface. The crest lies near the outer border of the moraine, the outer face being, as a rule, much more abrupt than the inner. As the moraine, where not interrupted by gaps, has a relief of 100 feet, the outer face often presents the abruptness of a river bluff. It differs, however, from a river bluff in the absence of erosion contours, there being instead a billowy slope, such as characterizes moraines. The erosion effected by streams since the withdrawal of the ice sheet is very inconspicuous compared with the inequalities of drift aggregation. The crest is usually so gently undulating as scarcely to suggest the strength of the moraine. It is not uncommon to find it so level for a space of one-fourth to one-half mile in width and for several miles in length that artificial ditching is necessary to give it good drainage. In such places there are usually shallow basins, 2 to 5 feet in depth, occupying an acre or more each, which add to the imperfection of drainage. The crest varies considerably in altitude independent of the gaps just mentioned, its highest points being about 900 feet above tide and its lowest about 800 feet. The range of 100 feet in

altitude, however, occupies a space of 1 to 2 miles or more, and hence is not conspicuous. The slopes usually present more undulations than the crest, but their swells seldom exceed 20 feet in height.

The combined belt east from Padua differs from the separate belts farther west in presenting greater complexity of features. Between Padua and Arrowsmith the trend of the principal ridges is northwest to southeast. One ridge with this trend passes immediately west of Ellsworth and constitutes the divide between Sangamon River and Kickapoo Creek. Another ridge leads into Arrowsmith from the northwest, which separates the Sangamon from the Mackinaw. From the vicinity of Arrowsmith eastward to the reentrant angle in Ford County the trend of ridges is southwest to northeast, or nearly at right angles with those west of Arrowsmith. The ridges just mentioned are low, with a relief of but 30 or 40 feet. There is a prominent crest along the south border of the combined belt which is interrupted by a small gap at the Sangamon Valley. It stands about 100 feet above the plain outside the moraine, and rises from that plain with the abruptness of a bluff line. The Sangamon River winds about through sags among ridges until it emerges from this morainic belt. Aside from the ridges and broad sags the moraine is characterized by a multitude of gentle swells 10 or 15 feet in height, among which there are shallow sags and occasional basins.

The reentrant in Ford County.—In the reentrant angle in Ford county the ridges on the west are crowded together in a single belt, but those on the east are in part separated by narrow strips of level marshy land which trend with the belt from north-northwest to south-southeast. The topography of the greater part of the reentrant portion is of a gentle swell-and-sag type, with undulations of only 15 or 20 feet. The ridges have definite crest lines standing about 50 feet above the marshy plains which separate them. In southeastern Livingston County, however, at the extreme north end of the reentrant, a sharp knob-and-basin topography is developed, in which knolls rise abruptly 30 or 40 feet above the basins inclosed among them. There are several small lakes and ponds among the morainic knolls, the largest of which occupy areas of 40 acres or more, but the majority occupy only a few acres each. From this point of the reentrant angle there is more or less knob-and-basin topography developed along the inner or northeastern slope of the moraine throughout its southeastward course

in eastern Ford and southwestern Iroquois counties. It is confined to a belt about 3 miles in width, and probably half the surface is of this type. The remainder is of a gentle swell-and-sag type. The expression is more subdued than at the point of the reentrant angle, and knolls exceeding 30 feet in height are rare. The basins are seldom occupied by ponds except in wet seasons. The contrast between this knob-and-basin tract and the gently undulating crest line of the moraine is quite striking.

Eastward from the Ford County reentrant to western Indiana.—The section of the Bloomington morainic system east from the reentrant angle presents a series of ridges grouped in two belts. The outer belt throughout its course in southern Ford and northeastern Champaign counties consists of a single broad ridge with billowy surface, having oscillations of 20 to 30 feet. As a rule, a well-defined crest is developed, but in places it completely disappears and the belt consists entirely of knolls and winding ridges, among which sags and shallow basins occur. Upon entering Vermilion County the outer belt soon displays a double-crest line, and in the eastern part of the county is separated into two ridges, as shown on the Danville topographic sheet, between which there is a narrow plain tract a mile or more in width that is drained by Stony Creek. This plain, however, is present for only a few miles, the ridges as a rule, being closely associated. The surface of the ridges varies from gently undulating to strongly billowy. The billows are seldom greater than 30 feet in height. The moraine varies 75 or 100 feet in altitude in Vermilion County, but the variation is not abrupt, a fluctuation of 50 or 75 feet usually occupying 2 miles or more. It rises very promptly on its south border, especially in the western part of the county. In Warren County, Indiana, this belt, or at least its inner part, curves around gradually to the northward and constitutes the divide between Vermilion River and Pine Creek. It is overridden in northern Warren County by a moraine of the late Wisconsin series, which has not obliterated it, but has simply dotted the surface with small knolls, the majority of which are less than 10 feet in height. The outer belt joins the inner in northern Warren County and the combined belt passes northeastward into Benton County, as indicated below.

Between the outer and inner belts of the portion of the Bloomington morainic system east of the reentrant angle is a narrow plain with very smooth surface, there being scarcely a knoll or undulation so much as 10

feet in height. This plain sets in in southeastern Livingston County, within 5 or 6 miles of the extreme north end of the reentrant, and is continuous through Ford, Champaign, and Vermilion counties, Illinois, and western Warren County, Indiana. Its greatest width is in Vermilion County, where it reaches a breadth of 7 or 8 miles, a portion of it extending into the northwest part of the area shown on the Danville sheet. Its breadth in Ford and Champaign counties is 2 to 5 miles.

The inner belt of this morainic system presents two, and in places three, crests in eastern Ford County. One crest leads from the point of the reentrant southward through Melvin, between two branches of the Vermilion River, to the vicinity of Henderson, where it crosses the eastern branch just above its junction with the western, and leads southeastward through Paxton along the north border of the river into Vermilion County. Another crest appears about 3 miles south of Roberts and leads southeastward, parallel with the crest just mentioned, crossing the extreme southwest corner of Iroquois County and fading out east of Paxton. A third crest leads from the extreme north end of the reentrant near Chatsworth, in Livingston County, in a course east of south, past Pope's Grove and Roberts, into southwestern Iroquois County near Loda, beyond which it is difficult to trace. It is on the slope of the third ridge that the knob-and-basin topography above mentioned is developed. None of the three crest ridges which this inner belt presents in Ford County and adjacent districts have strong expression. The outer one stands 30 to 50 feet above the plain tract outside (west) of it, but is not so prominent on its inner border. The other ridges rise only 20 to 30 feet above the border tracts. These crest ridges each have a breadth of half a mile or more. In a few places the outer crest carries knolls 20 or 30 feet in height. The outer crest is also more winding than the others, and has a border indented by extensions of the plain which enter it a half mile or more.

In Vermilion and Iroquois counties, Illinois, and Benton County, Indiana, this inner belt has a well-defined crest which forms the divide between the Iroquois and Vermilion rivers and which stands 3 or 4 miles back from the inner border of the moraine. This crest and the inner slope are gently undulating, with swells 10 to 20 feet in height. There is a gradual northward descent of perhaps 20 feet per mile to the inner-border plain. The crest usually is similar to the inner slope, but occasionally is sharply ridged,

as in the south part of T. 23, Rs. 13 and 14 W., where it rises abruptly 30 feet or more above the bordering portion of the moraine in a narrow belt a half mile or less in width. South from the crest just mentioned there is, in Vermilion and Warren counties, another ridge interrupted by occasional gaps. The ridge is continuous from the north fork of Vermilion River near Rossville eastward to its junction with the outer morainic belt at Pine Creek in northern Warren and southern Benton counties. West from Rossville it can be traced in a curving course southwestward to the Middle Vermilion, near Potomac, and thence northwestward up the north side of that stream. It is interrupted by a gap a mile or more in width immediately north of Potomac, and is deeply indented by valley-like sloughs at points farther east. In the vicinity of Blue Grass, in western Vermilion County, there is a plain occupying several square miles which separates this ridge from the one north of it. There is also a plain between the two ridges from the bend of Vermilion River south of Hoopstown eastward into Indiana as far as the ridges are traceable. The plain is scarcely 2 miles in width in the Illinois portion, but reaches a width of 3 or 4 miles in Indiana. The south ridge of this inner belt has usually a relief of about 50 feet above the plain on the south, and slightly less above the plane tracts lying between it and the north ridge. It is 2 or 3 miles in width, and its crest lies nearer the south than the north border. Its topography is similar to that of the north ridge, there being a gently undulating surface with few knolls more than 20 feet in height.

The portion covered by late Wisconsin drift.—This morainic system is conspicuous for 15 or 20 miles within the limits of the late Wisconsin drift, and, as noted above, probably embraces the belt of thick drift which leads eastward through central Indiana into Ohio. The north ridge maintains its usual strength to the vicinity of Fowler, Indiana, where it terminates abruptly in a marshy tract. The remainder of the belt swings around the eastern end of the north ridge and dies out in a gently undulating tract 2 or 3 miles east of Fowler.

It is a question whether the ridges in Benton County have suffered much reduction by the late Wisconsin ice invasion. That invasion formed only weak moraines in this district, consisting usually of belts of low knolls only 5 or 10 feet in height, which are accompanied by a great number of

bowlders, whose distribution in belts was long since noted by members of the Indiana survey. These belts of knolls and bowlders cross the ridges and intervening plains of the Bloomington system nearly at right angles in a NNW.–SSE. course, as may be seen by reference to the glacial map (Pl. VI). They assume greater strength a few miles to the north, there being a prominent morainic belt in northwestern Benton and eastern Iroquois counties, near the border of Illinois and Indiana. In this connection it may be remarked that the outer moraine of the late Wisconsin system is very variable in strength from place to place, and has a development about as weak in its passage across the Bloomington morainic system as in any part of its course.

The weak moraine in eastern Iroquois County, Illinois.—Of the weak moraines connected with the Bloomington system the first to receive consideration is the one which emerges from beneath the late Wisconsin series near the Illinois-Indiana line and passes westward into Iroquois County. This is maintained as a distinct ridge, 20 to 40 feet in height and scarcely more than a mile in width, for a distance of about 8 miles west from the State line, where it dies away on the border of Sugar Creek. It has a gently undulating surface, the swells seldom exceeding 10 feet in height. The probable continuation of this ridge is found in a poorly defined, undulatory belt which appears on the west side of Sugar Creek opposite the end of this ridge and leads westward to Onarga. It stands scarcely 20 feet above the bordering plains on either side and its surface is but little more undulatory than that of the plains. Its slight relief, however, is a matter of considerable consequence, since it stands too high for flowing wells to be obtained, while the neighboring plains furnish a large number of flowing wells from the drift. This belt does not connect definitely with the bulky ridges at the west, but as it is separated from them by a space of only 3 or 4 miles it seems to fall naturally into the same system.

Cropsey Ridge.—From the west side of the reentrant angle in southeastern Livingston County a small ridge leads westward, as already noted, past Cropsey, across northern McLean County, forming a divide between the Mackinaw and Illinois-Vermilion drainage basins. The portion east from Cropsey stands 30 to 50 feet above the plain on the south, and in places presents a very abrupt relief on that border. Toward the north it has a

more gradual descent to a plain which continues descending to the Vermilion River. This eastern portion of the ridge has numerous small knolls 10 to 20 feet in height and occasional shallow basins. From Cropsey westward the expression is somewhat weaker, though a relief of fully 30 feet is maintained as far west as the Chicago and Alton Railroad north of Lexington. There is also sufficient undulation of the surface to give this belt decided contrast to the plains on its border, swells 10 to 20 feet in height being quite common. West from the railroad the belt is definitely ridged for a few miles, but near Elpaso it becomes so obscure that further tracing and correlation has not been attempted. There are many places toward the north and west, in northeastern Woodford, eastern Marshall, southwestern Lasalle, and eastern Putnam counties, where, for a space of a square mile or more, the surface is quite as undulatory as in this morainic belt. It is possible that more detailed study will bring out a connection between these several undulatory tracts by which they may be thrown into a single belt. Possibly the divide between Vermilion River and tributaries of the Illinois flowing directly westward will prove to be the axis of such a belt. This divide, wherever it has been crossed by the writer, presents a slightly undulatory surface. The majority of the strongly undulatory belts, however, are found a short distance west of this divide. The surface is generally more undulatory west from the divide than east from it.

Chatsworth-Cayuga Ridge.—From the reentrant angle at Chatsworth in southeastern Livingston County northwestward nearly to Forrest the inner of the two weak members of this morainic system has sharp knolls inclosing basins, but their height is less than in the reentrant angle, seldom exceeding 25 feet. They occur on the slope as well as on the crest of the moraine. From the vicinity of Forrest northwestward for a few miles the moraine has a well-defined crest and is characterized by gentle swells 10 to 20 feet high. In sec. 34, Pleasant Ridge Township (T. 27, R. 7 E.), the single crest gives place to a double one, and two ridges are maintained from this point northwestward to the north branch of the Illinois-Vermilion River, the outer ridge coming to that river in sec. 14, T. 27, R. 6 E., while the inner comes to it in secs. 7 and 8, T. 27, R. 7 E. The outer ridge has a billowy crest, consisting of a series of slightly elliptical knolls, 25 to 40 feet high, 40 to 50 rods long, and about one-half as wide. These constitute an almost complete

chain leading from the river to the point of junction with the inner ridge. The inner ridge has not such a crest but, instead, a gentle swell-and-sag topography, with undulations of 20 to 25 feet.

At the east branch of the Illinois-Vermilion River this morainic belt is interrupted by a plain nearly 2 miles in width. The ridges are, however, both present north of the river. The outer one appears in secs. 33 and 34, Owego Township, and bears slightly west of north to Cayuga. The inner appears in sec. 31, Saunemin Township, and bears northward about 2 miles, and is interrupted by a gap through which Felkey Creek has its passage. It appears on the west side of this creek and bears northwestward, joining the outer one near Cayuga. Each of these ridges has a gently undulating surface, but upon becoming coalesced a sharply undulatory topography sets in, in which the swells stand 30 to 40 feet above the bordering sags and sloughs.

From Cayuga northwestward to northern Livingston County the moraine under discussion is so closely associated on the inner border with the Marseilles moraine as to be obscured by it, and is interrupted by several gaps where creeks tributary to the Illinois-Vermilion River traverse it. These gaps occur at the following streams: Wolf Creek, Deer Creek, Baker's Run, Mud Creek, and Blackstone Creek. The gaps are a mile or less in width, while the ridges which lie between them occupy a length of 2 or 3 miles. These interrupted ridges consist of a series of billows ranging in height from 10 feet up to 40 feet or more. The most prominent one noted is in sec. 18, T. 30, R. 5 E., and is known as "Smith's Mound." It occupies about 40 acres and stands nearly 50 feet above the surrounding country. Basins occur on its summit.

Farm Ridge or Grand Ridge.—In southern Lasalle County, just east of Streator, as noted above, a morainic ridge known as Farm Ridge and also as Grand Ridge emerges from the outer border of the Marseilles moraine. It appears to be the continuation of the Chatsworth-Cayuga Ridge. For a few miles, to Otter Creek Valley, it is separated from the Marseilles moraine by a narrow valley-like plain scarcely a mile in width. In secs. 29 and 30, T. 31, R. 4 E., it carries sharp knolls, but the remainder of the ridge in the interval between the county line and Otter Creek has a gently undulating surface. At Otter Creek there is a break a mile or so in width.

North of the creek the moraine consists of a series of knolls and sharp ridges standing 20 to 50 feet above bordering valleys or depressions.

In the southeast part of T. 32, R. 4 E., the moraine swings abruptly westward, passing through the village of Grand Ridge to Farm Ridge post-office. It carries knolls which rise to a height of 20 feet or more. Between Grand Ridge and Farm Ridge the topography is of a subdued knob-and-basin type. From Farm Ridge to the Illinois bluff near Utica there is a smooth ridge with very gentle undulations, but with a well-defined relief of 20 or 30 feet. This ridge is in places capped by sandy knolls 10 to 15 feet in height, apparently wind drifted.

The portion of this moraine north of the Illinois River consists of three disjointed ridges arranged end to end, but varying greatly in the direction which they trend. They may be traced readily on the Lasalle and Ottawa topographic sheets. The southern one has its southern terminus at the north bluff of the Illinois River between Little Vermilion River and Pecumsaugen Creek. It leads northward through Lasalle Township for 2 miles or more, then curves slightly and turns east of north, passing through secs. 30, 19, 17, 9, and 4, Waltham Township. It then drops down rapidly just north of the township line. The second ridge appears within a mile northeast of its terminus, and bears slightly west of north for a distance of about 3 miles, when it also drops off suddenly near Tomahawk Creek. North of Tomahawk Creek a third ridge appears, which bears northward for about 2 miles, then bends toward the northeast and comes to Big Indian Creek about 2 miles below Earlville. No well-defined continuation was found on the north side of this creek, though there are occasional knolls along the divide between Big Indian and Little Indian creeks, in both Lasalle and Dekalb counties, which may mark the line of its continuation, and which would connect it with the main portion of this morainic system east of Shabbona. The ridges whose courses have just been outlined have, as a rule, a sharp crest as well as swells and sags. The southern one is spoken of by the residents as the "Backbone," since it is quite sharp, standing in places 60 to 80 feet above the border districts, and being scarcely a mile in width. The ridge north of it has a height of 60 to 75 feet above the bordering plain, while the northernmost ridge has a height of 30 to 50 feet, except near its northern terminus, where it drops down to a height of but 15 or 20 feet.

THICKNESS OF THE DRIFT.

The thickness of the drift in the Bloomington morainic system is probably about equal to the measure of the relief above the outer-border district, which has a maximum of nearly 200 feet and which averages 75 to 100 feet along the ridges. The thickness is 50 feet or less between the ridges and on plane tracts north and east of them. Small valleys had been formed in the Shelbyville sheet prior to the Bloomington invasion, and these valleys were filled with the drift of the Bloomington morainic system. They appear, however, to have been usually but 30 to 50 feet or less in in depth, so that the thickness of the Bloomington sheet is not greatly increased at these lines.

The drift extends to some depth below the base of the Bloomington drift sheet. It is found that the earlier sheets of the Wisconsin series are present in considerable strength, as well as the Illinoian drift. The Iowan drift is present in northern Illinois, but its border, as already noted, passes under the Wisconsin in Bureau County. It is not known to be present beneath the Bloomington system south from Bureau County, unless it be on the inner border of the system in Iroquois and neighboring counties. This matter is discussed above in connection with the Iowan drift sheet.

In determining the lower limits of the Wisconsin drift, two conspicuous lines of evidence are drawn upon. One is an abrupt change in the texture of the drift, the Wisconsin drift being fresh and soft, while the underlying sheets are harder and more aged in appearance. The other is the occurrence of a black soil, beds of peat, or other decisive evidence of atmospheric action, produced at the surface of the lower or buried sheet of drift prior to the deposition of the later drift. In the portion of the Wisconsin drift lying outside the limits of the Iowan it is often an easy matter to decide upon the line of contact between the Wisconsin and the Illinoian by the change in texture alone. It is so marked that the majority of well drillers have recognized the two sheets even where no soil or peat has been preserved at their junction. Where the two lines of evidence are combined, it becomes an easy matter to decide upon the line of contact. It is not so easy a matter to decide upon the limits of the Wisconsin drift where it is underlain by the Iowan, for the contrast in texture is not so great as between the Wisconsin and Illinoian, though the Iowan is seldom so fresh in appearance

as the Wisconsin, even where deeply buried beneath it. There are numerous instances of the occurrence of buried soils in the portion of Illinois occupied by both the Iowan and the Wisconsin drift, and there is little doubt that such soils occur below each drift, but seldom are two soils found in the same exposure or well section. In a few cases the soils are referred with confidence to the junction of the Wisconsin and Iowan, but in the majority of cases they appear to be at the junction of the Iowan and Illinoian. An inspection of the well records presented below will serve to make clear the difficulties of interpretation.

These well records indicate that buried soils differ greatly in elevation within short distances in the portion of Illinois covered both by the Iowan and by the Wisconsin drift. This difference in elevation may be due either to the presence of two soil horizons or to an erosion of a buried drift sheet. In the latter case the lower soil would have been formed in a valley, while the higher would have been formed on the uplands. Were full records of wells preserved, it might be possible to interpret such cases satisfactorily. But usually the imperfections of the records are such that interpretations can scarcely be made. It is therefore only in the portion of the Wisconsin drift lying outside the Iowan that the lower limits of the Wisconsin are clearly recognized. It is highly probable that the Peorian and the Sangamon soil are each represented. A brief statement setting forth the variations in elevation of the buried soils in each of the counties occupied by the Bloomington morainic system will serve to make more clear the methods of interpretation as well as the difficulties of correlation in portions of the district.

In Kane County buried soils appear beneath a plain southeast of Burlington at a depth of only 40 or 50 feet and at an elevation of about 850 feet above tide. The soil is here referred with some confidence to the Peorian interglacial stage at the base of the Wisconsin drift. On the elevated moraine southeast from this plain a soil is found at a depth of 180 to 200 feet and at an elevation of only 750 feet. It has been found in several wells in the west part of T. 40, R. 7 E. This lower elevation is probably due to its being a lower soil horizon, presumably the Sangamon soil, at the junction of the Iowan and Illinoian sheets, though the instances reported may chance to be in every case in the line of valleys cut in the Iowan. The wide distribution, however, favors the interpretation that there

was a plain at about this level prior to the Iowan invasion. In the neighboring township on the south buried soils are reported in secs. 14, 15, and 20, at 675, 710, and 720 feet above tide, which are probably Sangamon. In the village of Elburn a buried soil occurs at 790 feet above tide, which is perhaps Peorian.

In Dekalb County only a few instances of buried soil were collected. These are nearly uniform in elevation at slightly less than 800 feet above tide and are slightly lower than the plain outside the Wisconsin drift. It seems probable that they should be referred to the Sangamon soil, at the junction of the Iowan and Illinoian. A buried soil is found beneath the Iowan drift, outside the limits of the Wisconsin, in the vicinity of Deerfield, at about the same elevation.

In southeastern Lee County soils occur at a level lower than the plain outside the Wisconsin drift, three instances being found where the elevation is 720 to 740 feet, while the plain is about 800 feet above tide. These seem referable to the Sangamon stage. One instance was found in sec. 34, T. 39, R. 2 E., of the occurrence of a buried soil at about the elevation of the outer-border plain; this may be referable to the Peorian.

In northwestern Lasalle County there are many instances of the occurrence of soil at 600 to 650 feet. This low elevation would suggest its reference to the junction of the Iowan and Illinoian rather than the base of the Wisconsin. This soil horizon is well preserved in eastern Bureau County. It seems to be quite uniform in elevation over several townships in which the surface of the Wisconsin has a variation of more than 100 feet in altitude.

In the counties south from Bureau County the Iowan drift has not been recognized, and possibly it does not reach these counties. No records were obtained which show buried soil either in Putnam or in Marshall County. In Woodford County wells in the vicinity of Metamora pass through a soil and enter a hard till at about 140 feet, or at an elevation of 680 feet above tide. A coal shaft at Minonk, in the eastern part of the county, passes from soft till into hard till at about the same elevation, though the depth of soft till there is only 62 feet. It is probable that in both of these instances the soil is referable to the Sangamon. In northern Tazewell County exposures were found, both in the Illinois bluff and along Farm Creek, where the loess occurs beneath the Wisconsin drift at an

elevation of about 625 feet. In these exposures the Peorian and Sangamon both occur as noted above. Instances of buried soil at an elevation of 625 to 650 feet are reported from the vicinity of Cooper, which are probably Sangamon. The Wisconsin drift ranges in thickness from 50 feet up to fully 150 feet in this portion of Tazewell County.

In northwestern McLean County instances of a buried soil and a change from soft to hard till are found at a depth of 150 feet beneath the crests of morainic ridges and at an elevation of 650 feet above tide. There are instances of "black clay" at lower levels, which may prove to be soil horizons. In the southwestern part of the county, in sec. 29, T. 24, R. 1 W., and sec. 3, T. 23, R. 1 W. (which are situated south of the Bloomington moraine), the fresh till extends to a much lower elevation than in neighboring districts. It seems probable, therefore, that there was a valley or concealed lowland tract traversing these sections. In sec. 3 a black muck was found below the fresh till at a depth of 200 feet and at an elevation of but 525 feet above tide. In the vicinity of Bloomington a black soil is found at an elevation of 625 to 640 feet above tide, which probably is of Sangamon age. Another buried soil occurs near the base of the drift at an elevation of about 540 feet. This is beneath a hard till and is perhaps preglacial. Northeastward from Bloomington the elevation of the surface of the Illinoian drift sheet is found to soon reach 700 feet; at least wells in T. 24, R. 4 E. enter a hard till at that elevation. One well in sec. 4 of this township is reported to have entered hard till at an elevation of 750 feet above tide. South from this township, in the vicinity of Leroy, a buried soil is found at an elevation of 740 feet above tide, which is probably under the Shelbyville or lowest Wisconsin drift sheet. Eastward the elevation of the surface of the Illinoian drift appears to decline to 700 feet or less, as shown by wells in southern Livingston, southwestern Ford, and western Champaign counties. The elevation continues decreasing toward the north and east across northern Ford, Iroquois, and Vermilion counties. The elevation of the Illinoian surface throughout much of Iroquois County and northern Vermilion County is 600 feet or less.

In Iroquois County, as noted above, there are two soil horizons, one being at the junction of the fresh and soft till with the harder till, the other being in the midst of the hard till. There is little doubt that the upper soil marks the base of the Wisconsin. But whether the sheet of drift which it

caps is Iowan or Illinoian has not been determined. Upon this determination must rest the age of the lower soil horizon.

Buried soils are exceptionally well preserved along much of the course of the Bloomington system east from the Illinois River, instances of their occurrence in well sections being much more numerous than in districts to the north, except limited areas in Bureau, Lasalle, Kane, and McHenry counties. There is scarcely a township in which the junction of the Wisconsin drift with older sheets may not be satisfactorily ascertained, either through the presence of the buried soils or by a change in the till.

STRUCTURE OF THE DRIFT.

Throughout the entire length of the Bloomington system the great mass of the drift composing its moraines, and also the plains between them and on their inner borders, together with earlier sheets of the Wisconsin series, consists of a soft blue till moderately stony and strikingly in contrast with the harder till found beneath it. The till is very adhesive, so that when excavated by a well auger it may be unrolled in great masses. The underlying harder till is far less adhesive. The surface portion of this till sheet is oxidized to a depth of 6 to 10 feet and has a brownish color. There are occasional developments of a pink-colored till. In places the pink color extends to great depth, but usually the blue color sets in within a few feet of the surface. The pink color is especially noticeable in the western and northern part of the morainic system, from Peoria County northward. Yellow till is also reported to occur in the midst of the blue till at many points. It apparently marks the surface of earlier sheets of the Wisconsin series. Its occurrence is known by well records only, no natural exposures having been found. Its degree of leaching and its state of oxidation are not known.

Associated with the till at various depths there are beds of sand and gravel, often of considerable extent, which afford a supply of water for many wells. It is not usual, however, to obtain strong wells within this drift sheet. In every county hundreds of wells have been sunk to lower horizons because of the inadequate supply found in this sheet of drift.

There are very few gravel knolls in the moraines of this system, though it is found that many knolls contain gravelly pockets in the till and these have been utilized to some extent for road ballast. The amount of avail-

able gravel, however, seems to be scarcely adequate to supply ballast for the wagon roads of the region traversed by the moraine. The composite belt with which this morainic system connects at the northeast is much better supplied with surface gravel.

As noted above, the outer face of the moraine in Lee and northern Bureau counties is heavily coated with sand, which apparently has been drifted by the wind from the Green River Basin on the west. From this sand belt southward through central Bureau County the surface of the outer ridge is in places coated with sand or a sandy loam. The texture of the moraine itself is also exceptionally sandy in that portion of the belt. Sand is found in the form of dunes along the east bluff of the Illinois River, from the bend of the river at Hennepin southward to the inner border of this morainic system. Sand deposits were also noted on the inner slope of the moraine in northern Vermilion County and west from the reentrant angle in southeastern Livingston County. It is probable that the sand deposits in both these localities are attributable to the presence of temporary glacial lakes held in front of the retreating ice sheet, whose waves worked upon the surface of the till sheet and formed the sandy beds there present. As noted below, sand in places assumes the characteristic features of beaches or shore lines in portions of the plains north of this morainic system.

The surface of this morainic system from the vicinity of Bloomington northward to Dekalb County is generally coated with a loess-like loam or silt to a depth of 2 to 4 feet. East from Bloomington this surface silt is so thin as scarcely to conceal surface bowlders. The silt also extends over the plain east of this morainic system in counties bordering the Illinois River, and has often a depth of 6 or 8 feet on these plains. It is especially prominent on the plain between the outer and inner belts in the Bureau Creek Basin, its average thickness being not less than 6 feet. From the inner belt eastward, in Bureau and Lasalle counties, it is less conspicuous than in the Bureau Creek Basin, being scarcely 2 feet in average thickness.

This surface silt was apparently deposited within a short time after the retreat of the ice sheet, for the underlying till sheet appears to have suffered no leaching prior to its deposition. The origin and mode of deposition of this silt or loess-like loam, like that on adjacent portions of the Shelbyville sheet, are as yet not clearly understood. The loess-covered plains on the west seem to afford a source of supply, and the prevailing winds, if in the

same direction as now, would have carried much atmospheric dust from them eastward. It is quite probable that some of the material was derived from this source, though perhaps only a minor part. It is found that this loess loam, when reaching a depth of 4 to 6 feet or more, is usually highly calcareous in its lower portion, while the loess of the outer-border districts is thoroughly leached to a depth of several feet. In all probability it had suffered considerable leaching before the ice sheet withdrew from the Bloomington morainic system. It is to be expected, therefore, that a non-calcareous or leached deposit would be made by transportation of dust from these plains. The presence of the calcareous material in the silt which caps the western border of the Bloomington till sheet seems to make it necessary to call in the action of glacial waters charged with fresh calcareous silt. The manner in which the silt was distributed is an unsettled question and one on which further light seems necessary. It will probably be found in a combination of aqueous and æolian agencies. As shown below, the drainage conditions on the outer border of the Bloomington system were favorable for the transportation of gravel by streams issuing from the ice margin. There would appear, therefore, to have been a rapid descent for these streams to the region south and west from the ice sheet. Such being the case, we can scarcely infer that the loess which covers the elevated parts of the morainic system was deposited by a sheet of water, for this would imply a general submergence. It is suggested that there may have been portions of the border district in which the waters found inadequate drainage. In such places silts may have been spread out which were afterwards transported by wind to the moraine. The matter, however, is one of conjecture rather than of demonstration.

Surface bowlders are numerous only at a few points on this morainic system, being rarely met where no sand or silt deposits are present to conceal them. But in this respect the Bloomington system is not different from other moraines of the early Wisconsin series. In Kane, Dekalb, and Ogle counties there are occasional bowlders along the crests of the ridges, but they seldom become conspicuous. On the plane tracts in these counties they are quite rare, but this is not a fair field for study because there is usually a sufficient amount of silt to conceal them. Bowlders abound along the outer face of the outer belt for a few miles in southeastern Lee County and on the crest and outer face at a few points in

Bureau, Marshall, and Peoria counties, there being some farms on which they are a serious hindrance to the cultivation of the soil. But much of the moraine in these counties is silt or sand covered to a depth of several feet, so that bowlders, if present, are concealed. In the portion of the morainic system between the Illinois River and Bloomington scarcely any surface bowlders were noted, though there the surface silts are several feet in depth. From Bloomington eastward there is generally a sufficient number of bowlders at surface or at slight depth in the soil to meet demands for some time to come in supplying foundations for buildings. In places they were so numerous that farmers have collected them in piles in the fields. Such is the case in the northern tier of townships of Vermilion County, both along the crest of the north ridge and on its inner slope. The bowlders range in size from 8 or 10 feet in diameter downward, the ordinary size being 2 to 4 feet. Granite bowlders predominate over other classes of rock along nearly the entire belt, and a few limestones were noted. Greenstones and quartzites are also common. The bowlders are in some cases much rounded by exfoliation, a feature which seems more conspicuous than in bowlders on the Shelbyville sheet. Numerous comparisons were made of bowlders embedded in the till with those found at the surface, and in almost every instance it was found that local or semi-local rocks are much more abundant in the till than among the surface bowlders. A much larger proportion of striated stones is also found in the till than at the surface; indeed, the surface bowlders are seldom striated. These are features which, as already noted, are generally characteristic of the till of the entire region under discussion in each of the several sheets represented. Occasionally very large limestone blocks are found at the surface or but slightly embedded in the drift. One block found a short distance northwest of Rossville, in Vermilion County, furnished several wagon loads of excellent building stone, and when first discovered was thought to be a ledge in situ, but subsequently proved to be a bowlder embedded in the till. In that vicinity the drift is about 200 feet in depth and is underlain by the Coal Measures. The nearest known outcrop of limestone is about 30 miles to the north.

Numerous well sections collected along the line of this morainic system are presented in the discussion of the wells in the latter part of this report, and these will serve to illustrate the variations in structure which this morainic system presents.

CHARACTER OF THE OUTWASH.

The writer's examination of the features on the outer border of the Bloomington morainic system covers the portion from Bloomington northward, and the discussion pertains chiefly to that portion. The portion eastward from Bloomington was examined some years since by Prof. R. D. Salisbury, but has received scarcely any attention from the writer.

It will be observed that the Bloomington morainic system forms the source of several streams whose courses are southward or westward from it through the outer-border district. It also forms the source of other streams which lead northward or eastward or southeastward through the inner-border district. Still other streams flow through this morainic system from the inner into the outer border district. Of the first class the several headwater forks of Wabash-Vermilion River, Sangamon River, Salt Creek, the two Kickapoo creeks, Sugar Creek, Green River, and the two forks of Kishwaukee River are worthy of mention. Of the second class, Iroquois River, the Illinois-Vermilion River, Bureau Creek, and the western tributaries of Fox River are illustrations. Of the third class the Illinois and Mackinaw rivers are the only examples in Illinois.

An examination of these valleys brings to light important contrasts. The streams which flow away from the outer border of the moraine are in most instances found to occupy valleys which had been excavated somewhat by streams which antedated the formation of this moraine. These valleys received the outwash from the moraine and were partially filled by it. The streams on the inner border of the moraine had not the advantage of previously formed valleys, and in consequence their channels are entirely the result of stream action since the withdrawal of the ice sheet from this morainic system. It is found that the valleys which lead away from the moraine through the outer-border district have in most instances a filling of gravel or sand which is definitely connected with the morainic system as an outwash from the ice sheet. The streams which lead from the moraine across the inner-border district are not thus characterized by sand-and-gravel filling. In some cases the streams issuing from the edge of the ice sheet had sufficient force to transport gravel for many miles away from the ice border. In other instances they were able to carry the gravel but a few miles, as shown in the discussion below. The extent of the gravelly and

sandy outwash along the borders of the Bloomington morainic system is outlined in the glacial map, Pl. VI, where it may be compared with that of other morainic systems. This comparison shows that the outwash was fully as extensive as in any substage of the early or late Wisconsin. It is, however, of a finer grade than in some of the later substages, a feature which seems to indicate that the attitude of the land may have been scarcely so favorable for vigorous drainage as in the later substages. In the following detailed discussion the valleys in the vicinity of Bloomington are first considered. From this point the valleys are taken up in order toward the west and north, along the outer border of the morainic system.

For a few miles southeast from the meridian of Bloomington there is a shallow, valley-like depression along the outer border of the moraine. It is about a half mile in width, and its surface stands 15 to 25 feet below the plain on the south and 75 or 100 feet below the crest of the moraine on the north. Its eastern end is near the village of Downs, at Kickapoo Creek. It leads westward across the interval between East and West Kickapoo creeks, and also across that between West Kickapoo Creek and an eastern tributary of Sugar Creek. Both branches of Kickapoo Creek pass directly across it, but the branch of Sugar Creek referred to follows the depression westward for a distance of 2 miles, and there turns away from the moraine. The depression is found to have a filling of fine gravel and sand of considerable depth, so that wells 10 or 20 feet deep do not reach its bottom. The gravel was carried from this valley-like depression for some distance down each of the valleys which lead away from it, and is preserved in the form of terraces which stand 20 or 30 feet below the level of the bordering plains and about 20 feet above the present stream bed. The gravel probably extends down at least to the level of the present streams. It would appear, therefore, that valleys had been excavated to, if not beyond, their present depth prior to this filling. The gravel filling was traced down Kickapoo Creek beyond Heyworth, a distance of about 10 miles from the outer border of the moraine. Just north of Heyworth it is preserved in a broad terrace which has been extensively opened for gravel by the Illinois Central Railway. How much farther down the valley the gravel was transported has not been determined. On the tributary of Sugar Creek which leads away from the western end of this depression the gravel deposits were followed continuously down to a point east of Shirley. They

were also noted at Funk's Grove and at points below. The gravel was apparently transported to the junction of this fork with a more western tributary. In each of these valleys the gravel is of medium coarseness and carries a moderate admixture of sand. The presence of the sand is thought to indicate that the current was not vigorous, though it may have been somewhat stronger than that of the present stream, for the latter finds it difficult to transport the coarser portions of the material even at flood stages. As these valleys are narrow, averaging scarcely more than one-fourth mile and seldom reaching one-half mile in width, the glacial streams which occupied them can not have had very great volume. The depression on the outer border of the moraine does not seem to fit in naturally as a part of the drainage which preceded the formation of the morainic system. As yet, no satisfactory explanation of its mode of formation has been found. Possibly it was formed in connection with the ice invasion, either by the ice or by waters issuing from it. It bears some resemblance to "The Fosse" on Nantucket Island described recently by Curtis and Woodworth in the Journal of Geology, though it has not a sand plain or overwash apron on its south border.[1]

On the branch of Sugar Creek which leads through the west part of Bloomington there is a belt of gravel 60 to 120 rods in width, which extends up the valley at least to the Bloomington waterworks in sec. 32, Normal Township, just outside the inner large ridge of the Bloomington morainic system. At its head it is merged with the flood plain of the creek, but from Bloomington southward it stands a few feet above the flood plain. The depth of gravel at the waterworks is about 30 feet, and it appears to maintain this depth for some distance below Bloomington. There is usually a yellow-brown silt 4 to 6 feet in depth capping the gravel. The gravel contains a large amount of fine material, so that sand is screened from it for plasterers' use. Large pebbles are rare, though it contains a few 5 or 6 inches in diameter. This branch of Sugar Creek reaches the outer border of the Bloomington morainic system about 5 miles below the waterworks. The gravel here spreads westward beyond the limits of the valley, covering the lower portions of the plain between this branch of Sugar Creek and one that leaves the moraine 4 miles to the west. Low till swells rise above

[1] Nantucket a morainal island: By G. C. Curtis and J. B. Woodworth, Jour. Geol., Vol. VII, 1899, pp. 226-236, Pl. I, Figs. 1-5.

the level of the gravel surface, showing that the deposit is thin. The western tributary also has gravelly deposits above the point of its emergence from the moraine, but these were not traced to their head. The distance to which the gravel deposits have been carried down the two branches of Sugar Creek beyond the border of the moraine is not ascertained, but it is known to be at least 10 miles.

Mackinaw River has its source on the inner border of the main ridges of the Bloomington system, but Cropsey Ridge, one of the weaker members of the system, lies north of the headwater portion of the stream. Gravelly deposits have been noted at a few points on the borders of the headwater portion. They have not, however, been traced into definite connection with Cropsey Ridge. There is not a continuous belt of gravel leading down the valley from this headwater portion. A section several miles in length was examined just below the crossing of the Lake Erie and Western Railway, in which no gravel filling appears to have been made. That portion of the valley was found to contain deposits of silt of considerable thickness which reach a level 20 or 30 feet above the present stream. Upon continuing down the valley to the inner border of the outer morainic ridge a gravel terrace is found to set in abruptly at an altitude about 50 feet above the stream. This terrace merges into low gravelly knolls at its head and on its border, and thus makes a definite connection with the moraine. As it stands somewhat higher than the silt-filled portion of the valley just above its head, there was probably a pool in that portion of the valley prior to the excavation of the gravel which forms the moraine-headed terrace, and the silt deposits just noted were probably laid down in this pool.

Mackinaw Valley appears to have been excavated nearly to the level of the present stream prior to the formation of the Bloomington system and to have had a width of nearly a mile. The terrace has been traced down the valley continuously from the moraine to the point where the Mackinaw enters the Illinois Valley in the eastern part of Sand Prairie Township, a distance by direct line of about 17 miles from the outer border of the moraine. The altitude of the terrace decreases about 100 feet in this distance, being 640 feet at the outer border of the moraine and 550 feet at the point where it joins the Illinois Valley. The stream falls 83 feet in the

same distance (from 573 to 490 feet), and the terrace maintains a somewhat regular altitude above it, being about 65 or 70 feet above it at the outer border of the moraine and 50 feet at the border of the Illinois Valley. The terrace apparently has little fall in the 3 or 4 miles occupied in crossing the moraine. The remnants of the terrace occupy nearly one-third of the width of the valley. Several good exposures of the gravel were found, and these quite uniformly show a coarse gravel and cobble near the surface of the terrace, with finer gravel below. The coarseness of the material is such as to indicate vigorous drainage, apparently stronger than that of the present stream.

A small northern tributary of the Mackinaw, Deer Creek, emerges from the moraine a few miles north from the point where the Mackinaw leaves it. This also carries deposits of gravel along the borders of the valley. It is preserved in small remnants flanking the slopes up a height of 20 or 25 feet above the creek at the point where the stream leaves the moraine. The upland plain stands about 20 feet higher than the upper limits of the gravel.

On Farm Creek, a tributary of the Illinois, entering opposite Peoria, there is a gravel deposit heading in the midst of the Bloomington system about 2 miles west of Washington. This has been traced continuously down to the Illinois River Valley, a distance of 8 miles. At its head it is nearly as low as the creek flood plain, being scarcely 10 feet above the stream, but its fall is far less rapid than that of the creek. The creek has a fall of about 180 feet in the 8 miles while the terrace falls scarcely 60 feet. At Farmdale the terrace stands about 85 feet above the creek and at East Peoria about 120 feet. The depth of the gravel on this terrace is usually only 15 or 20 feet, including a silt capping 3 or 4 feet in depth. The breadth of the valley in which it is deposited was apparently one-eighth to one-fourth of a mile. The present stream has in places formed a valley of greater width, but usually it is confined to narrower limits than the old valley. The valley in which the gravel filling was made had been nowhere cut to a depth of more than 40 or 50 feet below the bordering plain outside the Bloomington moraine, and the gravel filling has reduced this depth to about 25 feet. The work performed by the stream which preceded the gravel filling was therefore but a small fraction of the amount performed by Farm Creek since that filling.

GRAVEL OF EARLY WISCONSIN AGE AT PEORIA, ILLINOIS, FORMING A TERRACE WHICH STANDS ABOUT 170 FEET ABOVE THE ILLINOIS RIVER OR 600 FEET ABOVE TIDE.

(View taken by Dr. Samuel Calvin.)

On the Illinois River Valley there are extensive gravel deposits forming a broad terrace which occupies a gap in the Shelbyville moraine just below the outer border of the Bloomington moraine, a gap through which the river passes. The north part of the city of Peoria stands on this terrace and is commonly referred to as the bluff or upland portion, since it stands about 170 feet above the Illinois River. These deposits may prove to date from the Shelbyville substage of glaciation, though from their coarseness and general relations it seems more probable that they were connected with the Bloomington and represent the height of valley filling on the outer border of that morainic system. Their freshness certainly places them in the Wisconsin series. The following reasons for referring them to the Bloomington rather than the Shelbyville substage may be mentioned: (1) The terrace corresponds closely in elevation with the gravel terrace on Farm Creek just described, which connects with the Bloomington morainic system east of the Illinois River; (2) the terrace on the Illinois occupies a shallow valley cut into the Shelbyville till sheet; (3) the vigor of drainage corresponds to that of the Bloomington and is greater than seems elsewhere to characterize the Shelbyville substage of glaciation. A view in a gravel pit on this terrace appears in Pl. XIII. The gravel wherever exposed on this terrace is composed largely of limestone pebbles. The local sandstone and shale pebbles and the Canadian crystallines constitute only a small percentage of the coarse rock material. The sand and fine material found associated with the gravel are also calcareous. In places the gravel is cemented with lime. It is probable that the large percentage of limestone pebbles is due to the great number of such pebbles in the till of the Wisconsin sheet in that vicinity.

The highest well-defined terrace noted on the Illinois above Peoria, which seems referable to the Bloomington substage of glaciation, is found near the inner border of the moraine at and below the village of Chillicothe. It stands only 550 to 560 feet above tide, or 40 to 50 feet lower than the terrace on the outer border at Peoria. This difference is probably referable in part, if not entirely, to a reduction from the original height of valley filling, for a well-defined bank separates the top of the terrace from the portions of the moraine bordering it. The terrace in the vicinity of Chillicothe contains much coarser material than at points above or below. The extensive excavations for railway ballast reveal a mass of cobble and

bowlders 20 or 30 feet in depth. The excessive amount of coarse material seems referable to the contribution of such material from the overhanging ice during the building up of the terrace. For this reason the terrace has been connected with the Bloomington rather than a later substage. Possibly some cutting of the valley of the Illinois took place between the heavy deposition of gravel on the outer border and that near the inner border of the moraine, in which case the deposits near the inner border may not have been built up to the level of those on the outer border. This view seems supported by the observations farther up the valley, no remnants higher than that at Chillicothe having been found.

Down the valley from Peoria there is a rapid decrease in the altitude of the gravel terrace, a fall of 70 or 80 feet being made in the 10 miles to the mouth of the Mackinaw River, just below Pekin. There is a great expansion of the valley just below that city, in which the gravel has an elevation of 520 to 530 feet above tide, or 90 to 100 feet above the Illinois River. The gravel is capped by sandy deposits, which are in places drifted into dunes 20 to 30 feet or more in height. Gravel deposits are conspicuous down the valley beyond the mouth of the Sangamon River, but the material becomes finer in passing down the stream. The gravel has a height of about 500 feet above tide at the mouth of the Sangamon, or 75 to 80 feet above the level of the Illinois River. Farther down it gradually approaches the level of the river, the highest terraces near the mouth of the stream, which seem connected with the Wisconsin invasion, being but 40 to 50 feet above low water.

There appears to have been no gravel outwash into Kickapoo Creek Valley in northern Peoria County, although this stream follows the outer border of the moraine quite closely for a distance of 7 or 8 miles. Upon turning away from the moraine the creek cuts through the Shelbyville moraine, and it is probable that this offered an obstruction to the rapid escape of waters from the ice margin.

In southeastern Stark County there is a low plain extending back from Spoon River Valley to the Bloomington moraine which received a slight outwash from the moraine. A few exposures were found where gravel to a depth of several feet was deposited. It seems, however, to have been only a weak point of discharge, as the gravel deposits scarcely extend to Spoon River Valley, though this valley approaches within 6 or 7 miles of the

moraine and receives two tributaries which head in the moraine. There are other tributaries of Spoon River farther north which also head in the moraine, but these seem to have afforded only weak lines of escape for glacial waters.

The portion of the moraine bordering the Green River Basin in northern Bureau and southeastern Lee counties, as already noted, is coated heavily with sand on its outer face. The sand extends westward from the moraine down the Green River Valley, covering southeastern Whiteside and northern Henry counties and occupying the low tract between Green and Rock rivers. This sand is in all probability an outwash from the moraine, being too extensive a deposit to be referable to the action of lake waves. The sand apparently forms, over much of the district which it occupies, a coating 10 to 20 feet or more in depth. The depth is so great that natural exposures of underlying beds are rare and only a few wells reach its bottom. It is therefore difficult to ascertain whether there is much gravel outwash. Near the border of the moraine in northern Bureau County there are, however, a few exposures of gravel at the base of the sand which are thought to be an outwash from the moraine. The gravel appears to extend but a few miles west, for in the vicinity of the county line of Bureau and Henry counties wells indicate that the sand rests upon a compact clay.

At the head of the Green River Basin, in eastern Lee County, there is a gravel plain, covering about 25 square miles, whose eastern border is in the moraine. It extends back into the moraine a mile or more, along the east and south branches of Willow Creek, and there connects with gravelly knolls which dot the valley slopes and bottoms for 2 or 3 miles farther east. This gravel plain extends northward along the west border of the moraine to the south branch of Kite River at Steward. At this stream also the gravel plain connects closely with gravelly knolls which extend some distance up the valley into the moraine. The gravel extends only a few miles away from the moraine, scarcely beyond the east border of Inlet Swamp. The waters issuing from the ice sheet probably had sufficient strength to carry the gravel down the rapid slope to Inlet Swamp, beyond which they could carry only sand. There is considerable fall in the Green River Basin, but it is irregularly distributed, so that drainage even now is very imperfect.

On the outer border of the moraine in eastern Ogle County there is a depression due to a preglacial valley which was not completely filled. Into this depression considerable sand and fine gravel was carried by the waters issuing from this moraine. There were two lines of escape, the southern portion of the depression being drained westward through Kite River, while the northern portion was drained northward through Killbuck Creek. The sandy and gravelly deposits are thickest along the portion drained by Killbuck Creek, where they have a depth of 20 feet or more. In the portion drained by Kite River the average depth is but 5 or 10 feet, and portions of the depressed area have scarcely any surface gravel. The deposits in this depressed tract would be classed as a gravelly sand rather than gravel, the proportion of coarse material being very small. The streams issuing from the moraine in Dekalb County (South Kishwaukee River and Owen's Creek) have only a small amount of gravel and sand outside the moraine, and appear not to have been lines of vigorous discharge. Sandy material borders Owen's Creek for about a mile each side the stream from the vicinity of South Grove northward to the mouth. The material is fully as fine as that on Killbuck Creek. On the Kishwaukee the belt of sand and gravel is less definitely outlined, there being places where no sand or gravel is found on either side of the valley, while at other places it extends back southward from the valley to the moraine, a distance of a mile or more. It is probable that a portion of this sand and gravel is an outwash connected with the formation of the moraine, though it connects rather vaguely with the moraine.

In northwestern Kane County a plain of sandy gravel extends from the moraine westward to the valley of Coon Creek and leads thence down the valley to the north Kishwaukee. It there connects with belts of gravel which lead in from the east and north, all of which appear to be an outwash from the western border of the composite belt of moraines in McHenry County. A broad belt of gravel leads down the north Kishwaukee to its junction with the south branch near Cherry Valley. Below this point the valley is so narrow that gravel terraces are inconspicuous, though they continue to the Rock River Valley.

The conditions of drainage attending the formations of the minor moraines is next considered. The character of the outwash from the weak moraine in northern McLean County has received but little attention.

Gravel deposits of medium coarseness have been observed at and above Lexington on the headwater portion of Mackinaw River near the outer border of the moraine. They underlie the plain for only a short distance back from the river valley at these points. The extent of these deposits and their relation to the moraine have not been ascertained. It seems probable, however, that they are a glacial outwash.

The latest of the moraines in the Bloomington system follows the east border of the Illinois-Vermilion River throughout much of its course, a position that under present conditions would afford fair escape for the glacial waters. But at the time the moraine was forming, the channel now occupied by Vermilion River had not been excavated. The broad basin which it traverses has scarcely 20 feet descent in the 40 miles from Pontiac to the borders of the Illinois River. The conditions were favorable for the ponding or accumulation of water issuing from the ice sheet, as well as for water draining into it from the land areas on the southern and western borders. A belt several miles in width might have thus become submerged and a lake-like river formed. Even though the volume of water were great, the force of the current would be weak until the channel had been cut back several miles into the basin. The opening of this channel has been very slow, for it is now but partly accomplished, the main part of the channeling being in the portion below Streator. Evidence of a ponding of waters in this basin is found in deposits of sand and silt which cover it. The sand deposits are most conspicuous in the southern portion of the basin, and are there drifted in places into low dunes and ridges. From Pontiac southward the deposits consist of silt or fine sand. The ponding of waters and deposition of sand and silt probably began with the withdrawal of the ice sheet from the divide on the west border of the basin, and continued until the ice sheet no longer contributed its waters to the basin. This would involve not only the time when the moraine under discussion was forming, but also that embraced in the production of the Marseilles moraine. Possibly the ponding continued to much later date, though in less volume than at the morainic substages As shown below (p. 290), there was a discharge into this basin from a small glacial lake held in the basin of the Iroquois River. This line of discharge followed the east fork of Vermilion River, which passes through the moraine under discussion, 8 to 10 miles southwest of Pontiac. The character of the outwash appears

to have varied little during the long period in which the ice sheet discharged waters into this basin. For a few miles along the immediate borders of the river below the point where the East Fork enters this basin a fine gravel occurs, which was probably contributed by the outlet. There may have been less ponding of water at this time than when water was contributed by the ice sheet more directly to the basin. This subject is discussed more fully in connection with the glacial lake (pp. 290, 314, 336).

No doubt the Illinois Valley received considerable material as an outwash from this minor moraine, but as yet the deposits have not been separated from those made later, and nothing is known concerning the degree of coarseness of the material.

The portion of the moraine north from the Illinois in central and northern Lasalle County seems to have been no better favored for escape of water than that along the border of the Illinois-Vermilion. The plain west of it carries thin deposits of silt, but whether their deposition is largely referable to water issuing from this moraine is not known. Possibly wind transportation was an important factor in the deposition.

INTERMORAINIC TRACTS.

EXTENT OR DISTRIBUTION.

Under this topic are discussed the plains and gently undulating tracts among the ridges of the Bloomington system and a plain between the inner ridge of the Bloomington system and the Marseilles moraine. The intermorainic tracts are of much greater extent than the morainic, for the latter are restricted to narrow belts. About 90 per cent of the area embraced between the inner border of the main ridges of the Bloomington system and the outer border of the Marseilles system is here classed as nonmorainic. This area of about 6,000 square miles ranges in width from 25 to about 50 miles, being widest in central Illinois. It has a length of about 175 miles between northern Kane County, Illinois, where it connects with the composite belt of moraines, and western Benton County, Indiana, where it is shut off by moraines of late Wisconsin age.

GENERAL FEATURES.

The portion north of the Illinois River, embracing southwestern Kane, southeastern Dekalb, northwestern Kendall, northwestern Lasalle, and

eastern Bureau counties, shows a marked descent from northwest to southeast and a less marked descent from northeast to southwest. Its altitude along the border of the moraine declines from about 800 feet at the northeast to 700 feet at the southwest, or 100 feet in a distance of 50 miles. It declines an equal amount in scarcely 25 miles in passing from the border of the moraine southeastward to the bluff of Fox River. The altitude along the bluff of this river ranges from about 700 feet at the north to 620 feet at the south. Aside from the narrow morainic belt already discussed, which traverses this plain from Utica northward to Earlville, the surface is as a rule only slightly undulatory. There are, however, a few short eskers with associated chains of gravelly knolls—discussed below—and also scattering knolls 10 or 20 feet in height, all of which rise somewhat abruptly above bordering plains.

South from the great bend of the Illinois River the features are more varied than in the district just touched upon. The narrow strip on the west of the Illinois Valley descends rapidly from the moraine to the river bluff. It has a gently undulating surface, with a tendency to north-south ridging. East from the Illinois Valley there are nearly plane tracts interrupted by small areas with undulatory surface, which in places bear strong resemblance to the morainic belts. These undulatory tracts are most abundant in a belt a few miles in width that leads southward from the bend of the Illinois through eastern Putnam, eastern Marshall, and east-central Woodford counties, its eastern edge being near the divide between tributaries of the Vermilion and streams that flow westward to the Illinois. From this divide eastward to the Vermilion River the surface shows very little undulation. There is, however, a marked descent, the altitude of the divide being 700 to 750 feet, while the immediate borders of the Vermilion north from Pontiac stand but 620 to 640 feet above tide. The descent from this divide westward to the Illinois is very slight; indeed, in places east-west lines are nearly level from this divide to the border of the river valley.

There is a small tract south of Ottawa, occupying the interval between the inner ridge of the Bloomington system (Farm Ridge) and the Marseilles moraine, which has a nearly plane surface. It is crossed in an east-west direction by a sand ridge, discussed below. Another sand ridge follows the south bluff of the Illinois part way across this plain. Both

ridges appear to mark the shores of a lake-like expansion of the Illinois River, and represents two stages differing about 30 feet in level.

In northern McLean County a tract embraced between the inner border of the main ridges of the Bloomington system and the Mackinaw River Valley is gently undulating and is also dotted by occasional well-defined knolls 20 or 30 feet in height. It has a marked northward descent, the elevation along the Mackinaw River being 50 to 100 feet below the inner border of the moraine. North from the Mackinaw River, as already noted, there is a well-defined ridge (Cropsey Ridge) crossing the country in a WNW.–ESE. direction. From this ridge there is a gradual northeastward descent toward the Vermilion River. The greater part of the surface is plane or but gently undulating. There are, however, in southern Livingston County a few knolls and ridges of sand 10 or 20 feet in height. These knolls and ridges are probably the result of wind action rather than glacial features.

East from the reentrant angle of the Bloomington morainic system in Ford and southeastern Livingston counties there is a plain which covers the greater part of Iroquois County and extends slightly into bordering counties. The plain is bordered at the north by the Marseilles morainic system and at the east by the Iroquois moraine, a moraine of late Wisconsin age. It extends into the State of Indiana only a few miles, in northwestern Benton County. This plain descends toward the north, its altitude at the inner border of the Bloomington morainic system being about 700 feet and in northern Iroquois County only about 625 to 650 feet. It is crossed nearly centrally from east to west by a gently undulatory belt, discussed above as a possible continuation of the inner member of the Bloomington system. Aside from this belt the drift surface is nearly plane. There are, however, a few low sandy ridges in the western part of Iroquois County and numerous dunes in the eastern part. Some of these ridges appear to be beaches of a temporary lake, as indicated below. The dunes are, in all probability, a result of wind action upon the sand deposits of the lake bottom.

THICKNESS OF DRIFT.

There are present beneath these intermorainic tracts a sheet of fresh drift of Wisconsin age and older deposits of Iowan and Illinoian age. The thickness of the Wisconsin drift may be ascertained at many places by the

well records, which show a change from soft till to hard at the base of this deposit. It is much less than on the morainic ridges of the Bloomington system, and probably does not average more than 50 feet. In southern Kane County and thence southwest along the border of Fox River it appears to be but 20 to 40 feet, but at the inner border of the main moraine in Dekalb, Lasalle, and Bureau counties it is in places 100 feet or more. In the counties bordering the Illinois River it is 50 to 100 feet or more, but in the Vermilion Basin it scarcely reaches 50 feet. In Iroquois County it is 50 to 100 feet.

The older drift deposits are thin in the vicinity of Fox River and Vermilion River and the west-flowing portion of the Illinois River, but elsewhere within the tracts under discussion they are generally present in large amount, and there is probably an average thickness as great as that of the Wisconsin drift sheet. In portions of the Iroquois River basin 200 feet or more of the older drift is present, but in the remainder of the tract a thickness exceeding 100 feet is rare. By reference to the detailed discussion of the wells in the several counties embraced within these intermorainic tracts the variations in thickness may be seen.

STRUCTURE OF THE DRIFT.

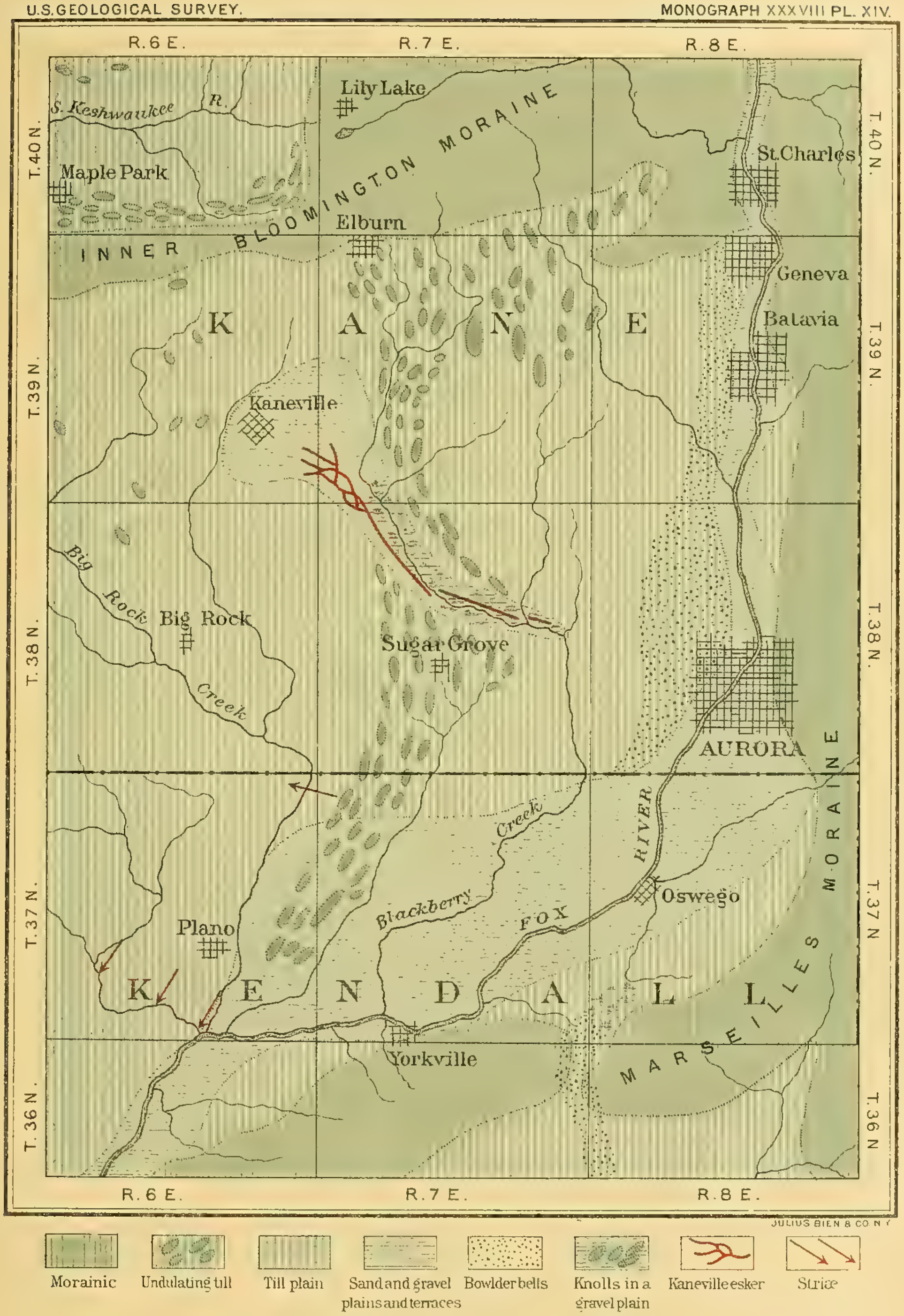
Throughout the greater part of the area embraced in these intermorainic tracts the Wisconsin drift consists mainly of a moderately stony, soft, blue till, very similar to that found in the moraines. This till is replaced by sand or gravel deposits along the line of the eskers which occur in Kane and Dekalb counties, and also along many of the tributaries of Fox River. There is also considerable sand associated with the till in a belt several miles in width along the west side of Fox River in Kane, Kendall, Dekalb, and Lasalle counties. On the borders of the Vermilion River in Livingston County and southern Lasalle County sand and gravel deposits predominate over the till. With these exceptions the till greatly predominates over the sand and gravel. In many localities it forms so solid a sheet that strong wells are not obtained in it, whereas in the districts in which sand and gravel predominate over the till abundance of water is obtained at moderate depths.

The drift of these intermorainic tracts is capped only by thin deposits of silt, seldom exceeding 3 feet in depth, and in places too thin to conceal the surface bowlders.

The older deposits of drift appear to be more variable than the Wisconsin sheet within the area under discussion. The till differs from that of the Wisconsin sheet in being much harder to penetrate and in being of a gray or brown color rather than blue. It appears to contain numerous pockets or intercalated beds of gravel or sand, for strong wells may usually be obtained in it in localities where the Wisconsin drift does not supply a sufficient amount of water. The outcrops of these older deposits along the ravines or valleys tributary to the Illinois often expose a cemented gravel, in beds a few feet in thickness and a few rods in extent. These beds appear to lead through the till in horizontal bands of limited width; possibly they are buried stream beds or valley gravels formed between the retreats and advances of an oscillating ice margin. The exposures are insufficient to afford a clear idea of their extent and connection. It seems not improbable that these beds which are cemented at outcrops along the valleys become open textured and water bearing where unexposed. There are places along the Illinois Valley and its tributaries where the older drift appears to be composed very largely of sand and gravel, but as a rule the till predominates. The structure of the drift in each of the counties comprised in this intermorainic area is shown in some detail in the discussion of wells which accompanies this report.

KANEVILLE ESKER AND DELTA.

One of the most interesting eskers noted in Illinois is found in the southern part of Kane County. Its eastern terminus is about 3 miles west of the city of Aurora, and its western terminus is near the village of Kaneville, from which the esker has received its name. The esker occupies a trough-like valley cut in glacial deposits. It is probable that the valley was formed by the same stream which deposited the esker, since they coincide so nearly in trend and position. At the western end of this valley there is an extensive delta, apparently built up by the same stream. The trough-like valley is now traversed by Blackberry Creek in the reverse direction from the supposed flow of the glacial stream which produced the excavation and formed the esker and delta. The valley occupied by the esker is much larger than that of the lower course of Blackberry Creek, its dimensions being about 1 mile in width and 30 feet in depth, while the valley of the creek below the point where it leaves this trough is scarcely 20 rods in



GLACIAL MAP OF PARTS OF KANE AND KENDALL COUNTIES

BY FRANK LEVERETT

Scale

5 0 5 MILES

1898.

average width and but 15 or 20 feet in depth. The trough-like valley is therefore about 30 times as large as the portion of Blackberry Creek Valley below its eastern end. This broad valley was apparently cut to such depth before the creek entered it that the latter has tended to fill it by overflows in time of freshet, and has deepened it only in the immediate bed of the stream.

The eastern end of the esker is found in sec. 18, Aurora Township, on a till plain which borders Fox River. There is here a ridge of gravel some 60 rods in length and 10 or 20 rods in width, which rises but 12 to 15 feet above the bordering plain. For a mile or more west from this ridge there are only occasional small gravel deposits in the form of knolls and short ridges, but as soon as the trough-like valley is fairly entered the gravel becomes more abundant. (See Pl. XIV.) It forms a winding ridge 20 to 60 feet in height, and interrupted only by occasional narrow gaps. Its slopes are very abrupt, rising frequently with an angle of 30°. In the northwest part of sec. 31, Blackberry Township, about 7 miles from the eastern end, the esker rises from the deeper portion of the valley and lies along its south slope. Here also it changes from a single sharp ridge to a tumultuous series of knolls and winding ridges, inclosing basins 30 to 40 feet or more in depth and having a diameter of but 10 or 20 rods. This belt has a width of about one-third of a mile, and extends westward nearly a mile. Just north of this main belt there are, in the deeper part of the valley, occasional gravel knolls and low winding ridges. These low ridges rise from the trough at its western end, and together with the main belt lose themselves in the gravel delta near Kaneville, the delta being built up nearly as high as the crests of the ridges.

The delta occupies an area of about 8 square miles. It stands a few feet higher than the till plain which borders it on the north, west, and south. The gravel apparently extends in places below the level of this till plain, for in two cases wells have penetrated to a depth of 60 feet without reaching its bottom. In the village of Kaneville, which is situated in the midst of the delta, the wells are usually in gravel to a depth of 30 or 40 feet. In a few instances, however, clay beds were passed through in the lower portion of the wells.

There are numerous small excavations in the esker which show it to be formed of sand and gravel in nearly horizontal beds. In places the beds

have a sharp dip toward the sides of the esker, but this does not appear to be a general attitude. The upper part and frequently the slopes consist of coarser gravel and contain less fine material than the deeper portions. The absence of fine particles is perhaps attributable in part to the action of percolating waters, which probably have sufficient force to carry down the finer particles a few feet from the surface, but it is probable that the surface portion was originally coarser than the deeper beds. The pebbles are mainly limestone and are apparently, in large part, from the Lockport (Niagara) limestone, which outcrops in the neighboring district on the east. The sand is calcareous, but not to such a degree as in many hillocks containing sand and gravel which occur in the neighboring moraines. It seems probable that the material of which the esker is composed is a residue left upon the excavation of the till which was removed along the course of the valley or of material embedded in the basal portion of the ice sheet. Examinations of a sample of the till from a neighboring till plain showed that 93 per cent of the pebbles are limestone, which is about the percentage of limestone in the esker.

Bowlders were observed on the esker in but one place, and this was at a slight depression on its crest. There were about 30 of them, and all were of Archean rocks. The greater percentage of Archean rocks on the surface than in the deeper portions, both of eskers and till sheets, apparently indicates a different source for the bowlders than that of the main body of the drift. Presumably they were carried at a higher elevation in the ice.

LITTLE ROCK ESKER OR "DEVIL'S BACKBONE."

In the northwest part of Squaw Grove Township (T. 38, R. 5 E.), Dekalb County, there is an esker about 1¼ miles in length, known by the residents as the "Devil's Backbone." It is situated a short distance south of Little Rock Creek in secs. 5 and 6, and trends ESE.–WNW. At the eastern end its height is but 4 to 6 feet, but in sec. 6 it is 10 or 15 feet in height. It is only 8 or 10 rods in width, including slopes, and consequently presents very abrupt slopes. It winds considerably, but has a somewhat even crest line. At the western end there is a sandy tract covering about 80 acres, which is thought to be a delta formed in connection with the esker. There is no valley or trough excavated in the drift, as in the case of the Kaneville esker, for the esker stands at about the level of the bordering till plain.

Wells in the delta penetrate 10 to 15 feet of sand before entering till. The esker is opened at numerous points, and there is usually 3 or four feet of coarse gravel at the surface, beneath which is a finer gravel. In places the bedding is found to have a dip toward the northwest, nearly in line with the general trend of the ridge. The coarse gravel curves over the ridge, covering slopes as well as crest. The pebbles are principally limestone and are usually well rounded.

There are a few short gravel ridges and knolls east from the end of this esker in secs. 4, 11, and 12, but they do not seem to be definitely connected with one another or with the esker. Their trend, like that of the esker, is ESE.–WNW. The same system of glacial drainage which formed the esker may have been influential in forming these knolls and ridges.

Mention should also be made of a chain of gravelly knolls which follows a tributary of Somonauk Creek in southeastern Clinton Township (T. 38, R. 4 E.), Dekalb County. Though following the creek border closely, they are evidently not the result of erosion by the creek, for they stand above the general level of the bordering plain. They range in height from 10 to 25 feet. Their width is usually 15 to 30 rods and the length varies from one-fourth mile or less to fully one-half mile. They are chiefly on the south border of the stream, but two were observed on its north border. They are not strictly in line with each other, though a belt a half mile wide would include the entire system. The length of the system is about 4 miles, the western end being 2½ miles south of Waterman and the eastern end at Somonauk Creek Valley in the southwest part of Squaw Grove Township. One of these knolls has an extensive gravel pit in which the following beds are exposed:

Section in gravel pit on knoll in Clinton Township, Dekalb County, Illinois.

	Feet.
Brown clay with a few cherty pebbles	4
Coarse gravel, mainly limestone pebbles	6
Fine gravel and sand in alternate layers, each 6 inches or more in thickness	4

Several other small excavations have been made in these gravel knolls which show a section similar to the above. The stratification in every case is nearly horizontal.

There are also knolls of a different type found on this plain which include much till as well as assorted material. One of these knolls, situated about 2 miles northwest of Leland, contains an extensive gravel pit which

displays its structure from top to bottom. The knoll is capped by a brown clay, containing few pebbles. Beneath this there is at the east side of the knoll considerable sand, but toward the center there is a series of till or clay beds 12 to 20 inches in thickness, interstratified with gravel and sand beds each 2 or 3 feet in thickness. All the beds dip toward the center of the hill at an angle of 15 degrees or more. The till is very hard and pebbly. The gravel contains a much larger percentage of crystalline rocks of Canadian derivation than is common in knolls and eskers made up entirely of assorted material, though there are many limestone pebbles such as may have been derived from ledges in the neighboring districts on the east. This knoll stands 15 to 20 feet above the bordering plain and about 30 feet above the flood plain of Little Indian Creek, which touches it on the east.

COVEL RIDGE.

In the plain drained by Covel Creek, a southern tributary of the Illinois, entering just below Ottawa, there is a low ridge about 7 miles in length extending in a nearly due east-west direction from near the outer border of the Marseilles moraine in sec. 4, Grand Rapids Township (T. 32, R. 4 E.), to the inner slope of Farm Ridge the inner ridge of the Bloomington system in sec. 5, Farmridge Township (T. 32, R. 3 E.). It has a height of 15 or 20 feet and a width of 40 to 60 rods, and is interrupted by no gaps of consequence except the one through which Covel Creek passes in sec. 6, Grand Rapids Township, and this gap is only 30 or 40 rods in width. The altitude of the crest of this ridge, as shown by the Ottawa topographic sheet, a portion of which is reproduced in Pl. XIX, is mainly between 640 and 650 feet above tide. The portion east of Covel Creek is represented to be slightly lower than 640 feet.

The ridge is capped by a brown silt several feet in thickness which is readily pervious to water. This is underlain by sand which extends to a depth of 15 or 20 feet or more. The few wells which have been made on the ridge are sunk no deeper than 20 feet. The sand also extends out beneath the bordering plain a short distance both north and south of the ridge and affords water for wells at slight depth. The extension beneath the plain, however, seldom exceeds a mile in width or half a mile from the crest of the ridge. Border districts are underlain at slight depth by till.

The internal structure, the form, and the uniform elevation of the ridge

suggest the interpretation that it is a beach line. However, this interpretation scarcely affords a satisfactory explanation of the mode of deposition of the silty mantle; hence the question of its mode of formation is left open.

There is a lower ridge following the brow of the Illinois bluff, which is well displayed in South Ottawa, and eastward from there to the border of the Marseilles moraine. Its altitude, as shown by the Ottawa topographic sheet, is very nearly 610 feet above tide. Along the north bluff of the Illinois, about midway between Ottawa and Marseilles, there is another beach-like ridge leading from the outer border of the Marseilles moraine westward to the border of Fox River Valley, which is represented to stand a few feet lower than the ridge just noted, its altitude being 600 feet or less.

ONARGA RIDGE.

In the Iroquois Basin there are several small ridges of sand presenting the appearance of beach lines, some being found in the northwest part of Iroquois County, a short distance south of the Marseilles moraine, and others on portions of the plain farther south. The best-defined and most elevated ridge noted is one leading from Onarga westward through Ridgeville to one of the headwater forks of Vermilion River, the west end being near the line of Iroquois and Ford counties, about 4 miles southeast of Piper. Throughout this distance of about 8 miles it has a width of only 40 to 80 rods and a height of 15 or 20 feet or less. As far as could be ascertained from the slight exposures and records of occasional wells it is composed entirely of sand. It is underlain at the level of its base by a bluish-yellow, silty, pebbly clay, which grades below into blue till. In some places the sand is immediately underlain by blue till. As a rule the ridge has a smooth surface and gentle slopes, but in places the sand is drifted into low dunes 5 or 10 feet in height. The sand is of a brown color and so far as tested shows no effervescence with acid. A short distance east from the eastern edge of this ridge a belt of low sand dunes sets in, which has a width of 1 to 2 miles. This belt leads eastward to the vicinity of Watseka, and thence northward and eastward to the Kankakee Basin, occupying much of northeastern Iroquois County.

The elevation of the Onarga Ridge is about 675 feet above tide, but the dunes to the east seldom reach this elevation, the district covered by them

having generally an elevation of 640 to 650 feet. Possibly a shore line may be found south and east of the dunes at an elevation corresponding to that of the Onarga Ridge, but as yet it has not been discovered. It seems probable that this ridge marks the south shore of a temporary lake which discharged westward through the east fork of Vermilion River. If there were no obstructions at the north, a northward discharge from the Iroquois Basin would seem to be more natural, for the country descends in that direction. The only known former obstruction is that caused by the presence of the ice sheet, in which case this beach may be interpreted as the shore of a glacial lake. The writer's studies have not been sufficiently detailed to justify a full interpretation of the phenomena. Other features of similar character are discussed below (pp. 336–338).

SECTION IV. THE COMPOSITE MORAINIC BELT OF NORTHERN ILLINOIS.

Numerous references have been made in previous pages to a composite belt of moraines with which the Bloomington system connects in northern Kane County, and which marks the continuation of the Bloomington system, together with that of later morainic systems which are there intimately associated with it. This composite belt admits of but little separation into distinct moraines. It seems advisable, therefore, to give it treatment independent of each of the morainic systems which lead away from it, leaving open to a large degree the question of precise correlation. This belt is made to include a somewhat distinct moraine, called the Marengo Ridge, which lies along its western border. The discussion of this ridge is first taken up; the remaining portion of the composite belt west of Fox River is next considered, and this is followed by a discussion of the portion east of Fox River.

MARENGO RIDGE.

DISTRIBUTION.

North from the village of Hampshire in Kane County, as far at least as the State line, the Marengo Ridge constitutes the outer moraine of the Wisconsin series, and it probably continues to be the outer moraine to its junction with the Kettle moraine of the Green Bay lobe in western Walworth County, Wisconsin.[1] The ridge receives its name from the village of

[1] See T. C. Chamberlin: Third Ann. Rept. U. S. Geol. Survey, p. 322; also Pl. XXXI.

Marengo, which is situated in the line of the ridge, but which stands in the North Kishwaukee Valley. It is the only town in Illinois in the direct line of the ridge, though Harvard in McHenry County and Hampshire in Kane County are situated near the foot of the outer slope.

From the State line the course of the ridge is nearly due south to Marengo, from which point it bears southeast to the south line of McHenry County. It then resumes a southward course and continues for about 18 miles to the vicinity of Elburn, in Kane County, where it becomes united with the portion of the composite belt to the east. It will be observed that it passes by the eastern end of the outer Bloomington ridge near Hampshire. The ridge throughout the greater part of its course has a width, including slopes, of 3 or 4 miles.

RELIEF.

The relief of the outer border is seldom less than 100 feet, and in places it reaches 150 feet or more. The inner border has a relief of 75 to 120 feet, but the relief appears less bold than on the outer border, because the ascent to the crest is more gradual. This ridge is closely associated with the remainder of the belt for a few miles south from the State line, and differs but little in altitude from the district on the east. Similarly at the south, where it connects with the remainder of the belt, it has about as great an altitude.

SURFACE CONTOURS.

From the State line southward to Hampshire this ridge presents a characteristic knob-and-basin topography, so well developed in the Wisconsin Kettle moraine and described by Chamberlin as being "of an exceedingly irregular, intricate character, formed by knobs, peaks, short irregular hills and spurs associated in complex order, interspersed with hollows and depressions of like irregular character, often without outlet."[1] The larger knobs rise scarcely 50 feet above the neighboring basins, and the average height of the knobs is probably not more than 25 feet. They are found both on the crest of the ridge and on the slopes. Aside from the well-defined basins, there are shallow, saucer-like depressions found frequently on the top of the knolls and the slopes of knolls and ridges, as well as in the sags between them. There is a marked distinction between the contours of the prairie

[1] Third Ann. Rept. U. S. Geol. Survey, 1883, p. 307.

and of the wooded portion of the ridge, the contours being much sharper in the forest than on the prairie. The ridge is mainly forest-clad from the State line south to the vicinity of Hampshire and mainly prairie from Hampshire to Elburn. This difference in the sharpness of contour may be due in part to the effect of the agencies of degradation, the wooded portion of the ridge being better protected from these agencies. It is probable, however, that the prairie portion was originally possessed of smoother contour. It presents a series of billows, often 40 or 50 feet high and 60 to 80 rods or more in diameter, whose slopes are usually smooth and regular. As indicated below, the relation of the southern portion of the ridge to the ice margin may be somewhat different from that north of Hampshire.

There are three gaps in this ridge worthy of mention. The largest is that at Marengo, through which the North Kishwaukee passes. It is fully 150 feet in depth and about 2 miles in width. The second gap occurs about 5 miles southeast of Marengo. This is nearly a mile in width, but only about 75 feet lower than the neighboring portions of the ridge. It has a nearly plane surface, and has apparently been utilized as a line of discharge for a body of water formerly held between this ridge and the one on the east. A third gap occurs in the north part of T. 40, R. 7 E. It is 60 or 70 feet in depth and about one-half mile in width. It has a nearly plane surface and was probably at one time a line of discharge for water held between this ridge and a moraine on the east. It is now utilized by a tributary of the South Kishwaukee River.

THICKNESS OF DRIFT.

The thickness of drift has been ascertained at only three points, but records of several deep wells were obtained which show that there is a heavy accumulation along the entire length of the ridge. Of the three borings reaching rock, one is in the village of Harvard and the other two are in the southern part of the ridge. At Harvard the thickness is 102 feet. In the other wells the rock was struck in one instance at 230 feet and in the other at about 250 feet. It is probable that the general thickness of the drift along the crest of the ridge south from Hampshire is not far from 250 feet, for wells on the plain west of the ridge, at an altitude 100 to 125 feet below the level of its crest, have in several instances struck rock at about 150 feet. One well on the ridge, near Lily Lake reached a depth of 336 feet without

entering rock. In the portion north from Hampshire the thickness is probably not much greater than the relief of the ridge, for rock is encountered at a depth of 50 feet or less in much of the border district on the west. The drift referable to the invasion which formed this ridge has probably a thickness about equal to the relief of the ridge, which, as stated above, is usually 100 to 150 feet or more.

STRUCTURE OF THE DRIFT.

The ridge is composed mainly of blue till. Sand and gravel beds are not sufficiently extensive to afford a general water supply. Even weak wells are difficult to obtain in some parts of the ridge. Many wells must be sunk 100, 125, or even 150 feet to obtain an adequate water supply. In not a few instances the water supply appears to be obtained at about the level of the base of the ridge and the junction between the Wisconsin and older drift sheets.

A few gravelly knolls were noted along the outer border of the ridge west of Marengo, and at occasional points between there and Hampshire. None of these rise more than 10 feet above the general level. A few gravel knolls were noted near East Burlington, in secs. 23, 24, 25, and 26, T. 41, R. 6 E., and low gravel ridges occur along the tributaries of the South Kishwaukee in Ts. 40 and 41, R. 6 E. Excavations in these knolls usually show a preponderance of sand and gravel over till, though the latter is often present in considerable amount. The beds have no apparent uniformity in direction or degree of dip. They are often curved and disturbed as if affected by movements of the ice sheet over them.

The presence of a buried soil was noted in several well borings of which records were obtained. In the city of Marengo, on the borders of Kishwaukee Valley, it is found at a depth of 30 to 60 feet, the variation in distance being due to difference in elevation of the wells. In sec. 11, T. 43, R. 5 E., a well on the outer slope of the moraine struck a buried soil at 70 feet. The soil was underlain by a soft whitish clay of slight depth, beneath which gravel, yielding water, was found. In the cases just noted the soil seems referable to the Peorian interglacial stage. A buried soil was noted in one of the deep borings in T. 40, R. 7 E., which reached the bottom of the drift. This soil, as noted on a preceding page, seems to be at a level low enough to be referred to the Sangamon. The boring is on

the farm of James Powell, in sec. 7, near the crest of the ridge, and the section is as follows:

Section of James Powell's boring near Lily Lake, Illinois.

	Feet.
Pebbly soil	1
Brownish-yellow pebbly clay	15
Grayish-blue pebbly clay	180
Black mucky soil	2
Greenish clay	3
Hard pebbly clay of brownish-blue color	40
Sand	2
Hard clay	8
Limestone	200
Total depth	450

The thickness of the yellow till in the above well section is greater than the average, though instances were found in which the till presented a yellowish color to a depth of 35 feet from the surface. The average depth of the yellow till is about 10 feet. Several sections of wells along this ridge are presented below in the discussion of the wells of Illinois. The till is thought by some well drillers to be slightly more stony in the ridges than on plane tracts in McHenry and Kane counties, but the difference is not very marked. Surface bowlders are common over the entire length of the ridge, and in a few places are very numerous. They are especially abundant in the vicinity of the McHenry-Kane county line and also near East Burlington. Bowlders are composed mainly of granitic and other rocks of Canadian derivation, limestones and local rocks being rarely found at the surface. In the till, however, limestone rocks are a conspicuous ingredient, and also in the kames or gravelly knolls.

CHARACTER OF OUTWASH.

Along the outer or western border of this ridge from the State line southward to Hampshire there is a nearly continuous gravel plain formed apparently as an outwash from the ice sheet. It extends out usually a mile or more from the foot of the moraine, and leads westward down the Kishwaukee Valley to Rock River. From Hampshire southward the plain outside Marengo Ridge is nearly free from coarse outwash and carries only slight deposits of silt and sand.

The gravel plains usually have a capping of loamy clay 2 to 6 feet or more in depth, which gives them great fertility. Beneath this clay are beds of sand and gravel which show considerable variety in coarseness in vertical

section. They vary also in coarseness from place to place at the same horizon. On the border of the gravel plains the assorted material rests upon beds of till belonging to the older drift, and the depth is often insufficient to afford water for wells. In the middle portions of the gravel plains the wells do not reach the bottom of the sand and gravel. Along the Kishwaukee near Marengo, Capt. Fred Smith, a well driller, has in some cases sunk wells to a depth of 100 feet mainly through gravel, but it is not certain that this deposit should be entirely referred to the outwash from the ice at the time the Marengo Ridge was forming.

INNER-BORDER PHENOMENA.

On the inner border of the Marengo Ridge there is, in Kane County, a narrow plain 1 to 2 miles in width, separating it from the remainder of the composite belt. This plain is generally very level and in places is poorly drained. It is underlain in part by sand and in part by till. The greater part is now tributary to Fox River, but the southern portion finds a discharge westward into the Kishwaukee through a gap in the Marengo Ridge, as noted above. In McHenry County the inner border of the Marengo Ridge is largely occupied by gravel plains which are connected with the portion of the composite belt on the east. Along the borders of these gravel plains there are nearly level tracts underlain at slight depth by till.

At present the gravel plains on both the inner and the outer border of the Marengo Ridge are occupied by insignificant streams which seldom fill the small ditches leading through the broad plains. They are certainly inadequate to have deposited the vast amount of assorted material here present, and the fact that these gravel deposits set in at the base of the moraines in just such positions as streams of water escaping from the border of the ice sheet would occupy, apparently leaves no room to question the interpretation that the gravel is an outwash from the ice margin. These gravel deposits, it is thought, testify as clearly, though perhaps in a less impressive manner, to the influence of the ice sheet as does the great ridge of commingled drift formed at the ice border.

CORRELATIONS.

The correlations of this ridge with moraines farther south can scarcely be said to be settled. Several interpretations are suggested by the

phenomena. By one interpretation the portion of the ridge from Hampshire northward is considered a continuation of the Bloomington system, while the portion south from Hampshire is merely a spur projecting back from the reentrant angle formed near that village. The difference in the contours of these two portions of the ridge may in this case be due to a different position in reference to the ice margin, the portion north from Hampshire being formed at the extreme margin of the ice sheet and the portion south from Hampshire at some distance back from the margin. The submarginal position would seem to be a sufficient cause for the smoothness of contour.

By a second interpretation the Marengo Ridge is made later than the outer ridge of the Bloomington system, and its entire length considered a marginal accumulation. Its great relief above the outer ridge of the Bloomington system at Hampshire, where it crosses that ridge, so strongly favors this interpretation that for some years it was given more weight by the writer than other interpretations, though the absence of a gravel outwash on the west border of the portion south from Hampshire left room for doubt.

A third interpretation suggested itself when revisiting the region with a view to reaching a more satisfactory conclusion concerning correlations. By this interpretation the outer ridge of the Bloomington system is considered to pass eastward across the Marengo Ridge and to join the composite belt lying east of that ridge. The portion of the Marengo Ridge north of Hampshire would, in this case, have stood outside the ice sheet, while the portion south of Hampshire would have been overridden by it. If the weakness of the outer ridge of the Bloomington system at the point where it connects with the Marengo Ridge is continued eastward some difficulty would be experienced in tracing it over the more bulky and more sharply morainic Marengo Ridge. The abrupt change in the contour of the Marengo Ridge at the point where the outer ridge of the Bloomington system connects with it seems to give support to this interpretation, as well as to the first interpretation.

Until further light is thrown upon the subject, the value of each of these interpretations must remain an open question. At present the writer is unable to exclude any of them, nor does any one of them seem decidedly better sustained by the phenomena than the others.

PORTION OF COMPOSITE BELT WEST OF FOX RIVER.

GENERAL FEATURES.

Aside from the Marengo Ridge just described, there is a belt from 8 to 15 miles in width, on the west side of Fox River, in McHenry and Kane counties, which is strongly morainic, there being only a few small areas, of 1 to 3 square miles each (aside from marshes and swamps included among the morainic knolls), in which the surface is level. The belt is more elevated on the west border than in the vicinity of Fox River. Its general elevation there is not markedly different from that of the crest of the Marengo Ridge. At the State line it rises above the 1,000-foot contour, one point being 1,040 feet above tide (Rolfe). A point a mile south of Alden rises above 1,000 feet. Along much of the divide between the Kishwaukee and Fox rivers, from the State line southward to Crystal Lake, the altitude is above 950 feet. In southern McHenry County and in Kane County few points reach 950 feet, but much of the divide rises above 900 feet.

Fox River enters the State at an elevation of 766 feet (Rolfe) and falls about 25 feet in crossing McHenry County, a distance by course of stream of over 30 miles. In Kane County its descent is more rapid, there being a fall of 125 feet in a distance no greater than that traversed by the stream in McHenry County. The stream is in the midst of morainic knolls and ridges as far south as Geneva, beyond which it has a plain on its west border. These ridges often rise abruptly 80 or 100 feet above the level of the stream. From the valley of Fox River, in McHenry and Lake counties, marshy valley-like tracts extend back several miles to the west and 2 to 3 miles to the east. These are traversed by sluggish streams similar to the upper course of the river.

Although the western border of this composite belt is, on the whole, more elevated than the district immediately bordering Fox River, it does not present so rough a surface, except perhaps in central Kane County, where a few square miles present a very sharp knob-and-basin topography. If a strip 3 or 4 miles wide along the west side of Fox River be excepted, the moraine in McHenry County presents few knolls that exceed 40 feet in height. The great majority are 25 feet or less. On the borders of Fox

River, as already noted, ridges and knolls in some cases reach a height of 80 or 100 feet. Numerous saucer-like depressions and occasional well-defined basins appear in all parts of this belt.

In northeastern McHenry County there is a small gravel plain known as "English Prairie," which stands about 100 feet above Fox River and occupies perhaps 3 square miles. It is about as elevated as neighboring portions of the moraine and is bordered by morainic knolls and ridges on every side. In the vicinity of Crystal Lake and Cary, in southeastern McHenry County, there is an elevated gravelly tract covering several square miles in which the surface is gently undulating and more subdued in expression than neighboring tracts composed more largely of till. The surface is not so level as in English Prairie. Immediately north of this gravelly tract, in the vicinity of Terra Cotta, there are broad swampy tracts nearly as low as Fox River which separate prominent ridges trending NNE.–SSW. These ridges continue prominent throughout the greater part of Ts. 44 and 45, R. 8 E.

In northern Kane County there are small plane tracts standing nearly 200 feet above Fox River which have been drained by an extensive system of ditches. These are almost completely surrounded by morainic knolls which rise 20 to 40 feet above their surface. Some of these knolls near Gilbert are very sharp. In the vicinity of the line of McHenry and Kane counties Fox River is bordered on each side by morainic tracts rising 150 feet or more above the level of the stream, and there is scarcely any marshy land on its borders southward from this line.

From the vicinity of Elgin southwestward to Lafox there is a belt 3 or 4 miles in width on the west side of Fox River in which sharp gravelly knolls and ridges abound. These ridges and knolls show a tendency to arrangement in chains trending nearly east–west, or about at right angles with the trend of the morainic belt. There are, however, not a few exceptions to this trend, some ridges being nearly in line with the morainic belt. These gravel ridges constitute the most prominent features in this portion of the moraine, many of them being 30 to 40 feet and a few 60 to 75 feet in height. They often rise very abruptly, so that their slopes are cultivated with difficulty. In the majority of cases these chains of knolls and ridges follow depressed areas standing 50 feet or more below the general level, and the present drainage lines in traversing these low belts wind about

among the gravelly ridges. In a few cases the knolls and ridges appear on elevated parts of the district.

In Campton Township (T. 40, R. 7 E.) the moraine is very elevated, some points reaching nearly 1,000 feet above tide, and presents a very sharp knob-and-basin topography. It has probably the sharpest knobs and the deepest basins found in the State of Illinois. The highest points rise about 150 feet above the border districts on the south and west and more than 200 feet above Fox River. Oscillations in level of 75 feet in a distance of 30 to 40 rods are not uncommon, and several beautiful lakelets of an acre or more each are sunk deeply in the midst of morainic knolls which surround them. This very strongly morainic topography appears at the point where the inner belt of the Bloomington morainic system connects with the composite belt under discussion. It also terminates the prominent portion of the composite belt so far as developed west of Fox River.

Upon passing southward from Campton Township a much lower country is entered than that to the north, the descent being similar to that found in passing southward from the inner border of the Bloomington morainic system in western Kane, Dekalb, and Lasalle counties. But instead of passing into a plane-surfaced tract, such as occurs on the inner border of the Bloomington system, an undulating tract is entered, which extends south to the border of Kendall County in a belt several miles wide. This tract contains a few very prominent knolls. One, known as Johnsons Mound, situated near the east fork of Blackberry Creek in sec. 15, T. 39, R. 7 E., rises about 150 feet above the level of the creek and covers fully 50 acres. A second prominent knoll, known as Bald Mound, because destitute of trees, is situated in sec. 23 of the same township. It rises about 80 feet above the border districts and covers perhaps 100 acres. It is elongated in a north-south direction, its length being about three times its width. Its southern end rises abruptly, but at the north it descends gradually to the gently undulating tract which borders it. A third knoll, known as Washburn's Mound, is situated between the other two in sec. 14, and stands about 50 feet above the bordering country. This mound is also elongated north to south, and has a length of one-half mile and a width of 40 to 60 rods. This mound has a more regular border than the other two, for they present spur-like projections which extend out 20 to 40 rods beyond a regular border. Aside from the three prominent mounds just mentioned the knolls

seldom reach a height of 25 feet, and many of them are 10 feet or less. The Kaneville esker described above has its trough mainly within this undulatory belt, but the delta lies entirely west of it in a very level country. There are occasional narrow sloughs or depressed areas 10 or 15 feet below the general level, which in most cases have connection with the present drainage lines. The upper course of Blackberry Creek is through a series of slightly depressed marshy tracts which occur among the low knolls of this undulatory belt. The undulations are maintained as far south as the line of Kane and Kendall counties, the southern terminus being at a gravel plane leading down Fox River. There is a narrow till plain between this undulatory belt and Fox River from Geneva southward similar to the plain which borders it on the west.

STRUCTURE OF THE DRIFT.

The drift of this portion of the composite belt is much more variable in structure than the Marengo Ridge. On nearly every section except in the gravelly belts above noted wells have shown that both till and assorted material are present. The till apparently preponderates over the assorted material, for the latter usually occurs in thin beds. In the gravel plain known as English Prairie and in the gravelly belt between Crystal Lake and Fox River there appears to be little or no till within 100 feet of the surface. The drift is mainly gravel and cobble, there being but little sand. In places fine laminated clays appear at some depth beneath till and gravelly deposits. The Illinois Central Railway exposes such beds in the deep cuts east of Plato Center. The till appears to be oxidized at surface to greater depth on this portion of the composite belt than on the Marengo Ridge, a feature which is probably attributable to the greater coarseness or porosity of the till, for it can not be older than the Marengo Ridge. In some cases the oxidation extends to a depth of 50 feet or more. However, the till is not everywhere coarse textured, for on some of the level tracts among the morainic knolls it is very compact. On low tracts near Terra Cotta, in eastern McHenry County, there is a compact silt used extensively for tile and also for terra-cotta ware. At several other places the silt is used for tile.

The presence of buried soils at great depth which are underlain as well as overlain by till is a not uncommon feature. In some cases the soils are

referred to the Peorian interglacial stage, for they probably occur at the junction of the Wisconsin and Iowan drift sheets. But it is possible that in many cases they are of Sangamon age and occur at the junction of the Iowan and Illinoian sheets. In the majority of cases they occur in the lower part of the drift. On the elevated portions they seldom are found at less than 125 feet from the surface, and in one instance (at Gilbert station) a soil was found at 180 feet. The drift on the elevated portions apparently averages not less than 200 feet. On the lower portions of the belt, in southern Kane County, the drift is correspondingly thinner. The buried soil is found at much less depth, but at about the same elevation above tide as in the higher portion. The occurrence of the buried soil, its depth and its relation to other beds of the drift, may be seen by reference to well sections of McHenry and Kane counties given on subsequent pages.

As noted above, this portion of the composite belt abounds in knolls and short ridges which are composed largely of gravel. These are largest and most numerous along the inner slope adjacent to Fox River, but are found occasionally on the elevated parts of the moraine—for example, near the north line of Kane County. These ridges occur both singly and in groups. They are also arranged in chains or narrow belts. They present considerable variation in structure. The majority have but little till with the sand and gravel, but some present a large amount of till in the lower portion. This is especially true of those on the elevated portion of the moraine in northern Kane County. In several cases the knolls are found to have a body of coarse gravel and cobble at their summits which extends downward in a funnel-shaped mass toward the center of the hill. In other cases the central portion of the hill is composed of sand and the gravel and cobble is found in the peripheral portion. A knoll in sec. 14, T. 42, R. 7 E., opened extensively for gravel, is found to contain alternations of till and assorted material. The till apparently forms a network of connections around lenticular masses of gravel. In most instances the gravel and cobble is found to extend scarcely as low as the base of the knolls. Borings have sometimes been made in the bottom of the gravel pits, and these usually penetrate a considerable depth of oxidized till. Indeed, the oxidation appears to be fully as deep beneath these knolls as the average depth of surface oxidation outside the knolls. The bedding of the assorted material is seldom horizontal, but curves and dips as if the material had been subject

to much disturbance after deposition. In this respect these knolls and ridges differ from the bedding usually displayed by eskers.

Bowlders are found in moderate number over all parts of the moraine. They are especially abundant in a belt extending from Gilbert station northward to the vicinity of Crystal Lake. The belt is widest near the Kane-McHenry county line, having there a width of about 4 miles. There is probably significance in the fact that this bowlder belt borders the head of the Kishwaukee gravel plain, which was an avenue of discharge for the glacial waters.

The bowlders are usually crystalline rocks of Canadian derivation, but there are also present large limestone blocks, which in some cases will furnish several wagon loads of building stone. These are especially abundant west of Elgin, and are found occasionally farther north, in both Kane and McHenry counties. They are apparently derived from the ledges of Lockport (Niagara) limestone, which underlie the district immediately to the east and probably extend into the district covered by this moraine. In some cases these large masses of limestone have led the residents to suppose that the rock is in situ and that extensive quarries might be opened by the removal of a slight amount of drift. The error of this interpretation has usually been discovered upon quarrying a few loads of stone. Wells west of Elgin, in the neighborhood of these limestone blocks, indicate that the drift there has an average thickness of more than 100 feet. Whether the supposed limestone outcrop in eastern McHenry County, mentioned in the Geology of Illinois,[1] is a ledge in situ or a transported block similar to those just mentioned was not ascertained.

CORRELATIONS.

Satisfactory correlations of this portion of the composite belt with the more clearly differentiated moraines in the districts to the south have not yet been established. Two quite distinct interpretations have been suggested in the course of the investigation. By the first interpretation this portion of the composite belt is made to be the continuation of the inner part of the Bloomington morainic system, which connects with it near Elburn. The very strongly morainic tract immediately northeast of Elburn would, in this case, be situated at a sharp bend or reentrant angle in the ice margin, and

[1] Vol. IV, pp. 131, 132.

this may account for its greater ruggedness. The undulatory tract leading southward from this sharply morainic portion might by this interpretation be accounted for as a spur extending backward from the sharp bend in the margin. The bulk of the Bloomington system is not greatly different from that of the composite belt west of Fox River and presents no obstacles to this interpretation. The topography of the composite belt is much sharper in expression than that of the Bloomington system, but changes of topography have been found to occur in other belts to as marked a degree as in this instance. As pointed out by Chamberlin, in the Third Annual Report, the Kettle moraine changes from a very sharp knob-and-basin topography in southern Wisconsin to a comparatively smooth swell-and-sag topography in northeastern Illinois and northwestern Indiana, and again assumes a sharp knob-and-basin topography when traced into Michigan.

By the second interpretation this portion of the composite belt is thrown into the late Wisconsin series of moraines and its continuation found in the bowlder belts and feebly developed morainic tracts lying outside the Valparaiso morainic system in Kane, Kendall, Grundy, and Kankakee counties. These belts can be traced into a reasonably close connection with the southern end of the undulatory belt in southern Kane County. There seems to be, therefore, no formidable gap to bridge in making this correlation. The greatest obstacle to the interpretation appears to be found in the abrupt change in bulk which the moraine presents in the district east of Elburn. From this point southward a thickness of only 20 or 25 feet is presented by the moraine, where best developed, while to the north the thickness averages more than 100 feet. The expression also is much stronger north than it is south from this line.

Perhaps by combining these interpretations a solution may be found. The great bulk of the portion north from Elburn and the very strong expression of the portion immediately northeast of Elburn may be a result of the invasion which formed the Bloomington morainic system. At the late Wisconsin invasion this region may have been partially overridden by the ice, but without greatly modifying its appearance and without depositing a greater amount of drift than is found in the gently undulatory belt in southern Kane County and the feeble moraines in the district to the south. In this case the gently undulating tract in southern Kane County may be largely the result of the late Wisconsin invasion, though the interpretation

that it is a spur from the reentrant angle in the Bloomington system need not be set aside.

The Kaneville esker lies mainly within the limits of this undulatory belt and seems to have been formed at as late a date. Its western end, together with the delta, extends beyond the line of the bowldery tracts referred to the late Wisconsin invasion. This fact seems to throw the balance of evidence in favor of the correlation with the Bloomington system. Furthermore, the Kaneville esker seems to be a part of the series of gravelly knolls and ridges above mentioned which are developed along the inner border of the Bloomington morainic system in the district to the west. It is possible that chains of gravelly knolls and ridges which lead westward from Fox River Valley in northern Kane County into the higher portions of the moraine were formed at the same time as this esker and under similar conditions. The prominent knolls which occur in the midst of the gently undulating belt—Johnson's Mound, Ball Mound, and Washburn's Mound—may also be included in the same category. They appear to be composed largely of gravel, though their structure is known only from two well sections on their higher parts and slight excavations on their borders.

PORTION OF COMPOSITE BELT EAST OF FOX RIVER.

DISTRIBUTION AND CONNECTIONS.

From the vicinity of Elgin northward to the Wisconsin line the valley of Fox River alone separates a morainic tract on the east from one on the west side of the river, and throughout much of this interval the stream winds about through lakes and marshes among morainic knolls without forming a well-defined valley. Southward from Elgin the composite belt separates into distinct moraines, between which are plane tracts. One of these moraines, called the Valparaiso, swings around the head of Lake Michigan; another, called the Marseilles, follows nearly the east bluff of Fox River south and west to the Illinois River. As already noted, a weak morainic system of late Wisconsin age leads southward, and the Bloomington system southwestward, from the portion of the composite belt west of Fox River.

The equivalency of the Valparaiso morainic system to the eastern portion of this composite belt is established beyond doubt. Probably it should include all of the composite belt north of Elgin on the east side of

Fox River, and possibly it also includes a small part west of this stream. It may extend as far west as the east border of English Prairie, at the State line, and may embrace the tract between Fox River and Crystal Lake outlet, farther south.

The equivalent of the Marseilles morainic system in this composite belt is not satisfactorily determined. From northern Kendall County northward it appears to have been overridden to some extent by a later advance of the ice, and is perhaps completely concealed by the later deposits within this composite belt.

The portion of the composite belt east of Fox River has a width ranging from 6 or 7 miles at the State line to about 15 miles at the south line of Lake and McHenry counties. Between these lines it is mainly in Lake County, but includes a narrow strip in eastern McHenry County. From the south line of these counties southward to Elgin it lies mainly in Cook County, but includes the east border of northern Kane County and maintains a width of 14 to 15 miles. This is about the width of the Valparaiso system farther south.

GENERAL FEATURES.

The general elevation of this portion of the composite belt is lower than in the portion west of Fox River, being but little more than 800 feet above tide. The highest points are found in southern Lake and northwestern Cook counties, and they rise but little above 900 feet. One of these, just east of the village of Volo, stands 913 feet, and one in the northwest corner section of Cook County 910 feet, as determined by the barometric survey under Professor Rolfe. There are, however, but few other points rising above 850 feet.

There is a well-defined ridge-like crest standing 20 to 40 feet higher than border tracts and having a width of about one-half mile which leads southward with a somewhat winding course through western Lake and northwestern Cook counties, forming the water parting between Fox and Des Plaines rivers. East from this crest line there are only gentle swells, seldom more than 15 feet in height, among which are occasional ponds and small lakes. This district presents a slope which descends eastward at the rate of 20 to 40 feet to the mile as far as the Des Plaines Valley. West from the crest line the surface is much more varied, there being tracts

covering a few square miles in which a sharp knob-and-basin topography is developed, around which are gently undulating tracts, such as occur on the east slope. There are also extensive marshes west of this crest, and the drainage is generally less perfect than on the east slopes. Lakes abound in Lake County on both the west and the east slopes. They range in size from an area of several square miles down to an acre or less. They are usually bordered wholly or in part by knolls and ridges which rise 10 to 50 feet above their surface. In some cases extensive marshes border one or more sides of the lakes. These lakes, with their bordering hills dotted with groves, add greatly to the beauty of the scenery. The lakes and also basins become rare southward in Cook County. The few which occur are very small and shallow.

THICKNESS OF DRIFT.

Records of several deep borings were obtained which give an average thickness of about 200 feet of drift. Six borings failed to reach rock at an average depth of about 250 feet, one of them being 315 feet. As these borings are widely distributed, it seems probable that the general level of the rock surface is fully 200 feet below the drift surface. The underlying rock is limestone and presents a very uneven surface. The well borings indicate that valleys had been cut to depths of 200 feet or more prior to the drift deposition. Hence borings in the lines of these valleys, when located on high parts of the moraine, probably would encounter fully 400 feet of drift. The thickness of each of the several drift sheets here present has not been worked out so fully as in some other localities, but the drift of Wisconsin age apparently averages not less than 100 feet in depth, and may average 150 feet.

STRUCTURE OF THE DRIFT.

The upper portion of the drift to a depth of 100 to 150 feet consists mainly of till. The till is usually oxidized at surface to a depth of 10 or 15 feet, beneath which it presents a blue-gray color. It is also generally soft and fresh, and seems to be referable to the Wisconsin, though it may also include the Iowan. At greater depths than 100 to 150 feet borings encounter either a hard gray till tinged with brown, probably Illinoian, or beds of sand and gravel, or an alternation of till with sand and gravel. Wells near Lake Zurich have in several instances encountered thick beds of

fine sand below the till, setting in at 100 to 140 feet and extending to 250 or 300 feet. At Barrington, and for several miles southwest, wells often encounter a hard till at 100 to 160 feet which contains very little sand. In the vicinity of Ivanhoe and Wauconda wells pass through alternations of sand and gravel with hard till after leaving the sheet of soft till.

In southern Lake and northwestern Cook counties the sheet of soft till is generally a poor source for strong wells, such as are required on dairy farms, though wells adequate for household use may usually be obtained at convenient depths. In the northern part of Lake County strong wells are often obtained without reaching the bottom of the Wisconsin drift sheet. The greater amount of sand and gravel found in the older drift sheets has led to the sinking of many wells to these sheets at depths of 150 feet or more. Further data are given in the detailed discussion of wells.

There are but few gravel knolls in either Lake County or Cook County, but such knolls are not rare on the borders of Fox River in eastern Kane and McHenry counties. Knolls composed mainly of till have in some cases pockets of gravel at or near the surface, which supply material for wagon roads. There are few localities west of the crest where gravel may not be conveniently obtained, but east of the crest it is not so well distributed.

Surface bowlders occur in moderate numbers over all of this district. They are nearly all crystalline rocks of distant derivation, there being very few limestone or local rocks. The till is thickly set with limestone rocks as well as with those of distant derivation.

SECTION V. THE MARSEILLES MORAINE.

DISTRIBUTION.

This moraine next succeeds the Bloomington morainic system in the Wisconsin series. The name is taken from the village of Marseilles, situated at the point where the Illinois River cuts through the moraine.

The moraine is readily traced as far north as South Elgin, 4 miles south of the city of Elgin, where it is lost in the composite belt just discussed. For about 25 miles south from South Elgin it is combined with a till ridge called the Minooka Ridge, and follows the east side of Fox River closely, past St. Charles, Geneva, Batavia, and Aurora, the eastern parts of

these cities occupying its outer face. There is usually but a single crest, and it follows nearly the county line between Kane and Dupage. The width of the belt is 2 or 3 miles. The combined belt continues about 6 miles farther south than Aurora, along the line of Will and Kendall counties, leaving a strip 2 or 3 miles wide between the river and the moraine. The Marseilles moraine there swings abruptly westward, coming to the river bluff between Oswego and Yorkville, while the Minooka Ridge continues southward to the head of the Illinois River. The Marseilles moraine follows nearly the southeast bluff of Fox River to the mouth of the stream, its outer border being nowhere more than 4 miles and usually less than 1 mile from the stream. The width in Kendall County is only 2 or 3 miles, but increases to 5 or 6 miles in northeastern Lasalle County, near the north bluff of the Illinois River.

At the Illinois Valley the moraine changes abruptly from a south-southwest to a south-southeast course. Its south-southeast course is maintained in a belt 3 to 5 miles wide passing through southeastern Lasalle and northern Livingston counties. In the latter county, as above noted, it is closely associated with Farm Ridge, a weak inner ridge of the Bloomington system. In the vicinity of Odell the moraine swings around eastward, and near the line of Livingston and Ford counties takes a course north of east, occupying in its curving portion a width of 8 or 10 miles. This course is maintained across northern Ford, northwestern Iroquois, and southern Kankakee counties, to the vicinity of Ste. Anne, where it changes to southeast. From northern Ford County to this point it has a width of 3 to 5 miles. The southeast course is maintained to the vicinity of the State line northeast of Donovan. Here this moraine meets the Iroquois, a moraine of the coalesced Erie-Saginaw lobe. Its relations to that moraine are still obscure, though the courses of the two moraines seem to be nearly coincident in Newton and Jasper counties, Indiana. Its width before connecting with that moraine is 1 to 2 miles. The combined moraine has a width of 3 to 6 miles and is traceable as far as Medaryville, in Pulaski County, Indiana, beyond which it seems either to die out or to be concealed beneath the "Lake Kankakee" sand ridges. Possibly this combined moraine constitutes an interlobate belt, but, as indicated below (pp. 318, 327), it seems more probable that it is a result of two advances differing in date as well as direction.

RANGE IN ALTITUDE.

The Marseilles moraine displays very little range in altitude. The crest varies scarcely 25 feet from the 750-foot contour, and the lower parts of the moraine stand near the 650-foot contour. Throughout much of its course the 650-foot contour follows approximately the outer border of the moraine. The inner border is somewhat higher, but as a rule falls below 700 feet.

RELIEF.

The above statements concerning range in altitude may be readily applied in reference to the relief of the moraine. On the outer border it averages about 100 feet; it is seldom less than 50 feet and in places reaches 125 feet. The relief on this border is least in the northern and the eastern portion of the belt, in places being 50 feet or less. The middle portion, except where combined with the weak inner ridge of the Bloomington system (Farm Ridge), has a general relief of 75 to 100 feet or more. On the inner border the relief seldom exceeds 50 feet, and for a few miles at the north scarcely exceeds 25 feet.

SURFACE CONTOURS.

Throughout much of its course the Marseilles moraine has a well-defined crest, and this, as a rule, constitutes a water parting. North of the Illinois River it separates the tributaries of Fox River from those of Dupage River, Au Sable Creek, and Nettle Creek. South of the Illinois it separates tributaries of the Vermilion River from those of Mazon Creek and Kankakee River. In eastern Illinois, however, it does not constitute an important water parting, being crossed by the Iroquois River; and in western Indiana it is crossed by tributaries of that river. The crest is sharpest for a few miles in the central part of Kendall County, south and southwest of Yorkville, where it presents a narrow ridge standing 30 to 40 feet or more above bordering portions of the moraine. Usually the crest is a broad, gently undulating ridge 1 or 2 miles in width. Along the crest, as well as on the slopes, there are saucer-like depressions containing water, except in seasons of drought, and often occupied by clumps of willows. The swells are usually low, seldom exceeding 20 feet in height, and have gentle slopes. However, in parts of Livingston County, southeast of Odell, the swells in some cases reach a height of 50 feet above sloughs inclosed among them. There is

also a group of prominent knolls in the vicinity of the line of Kankakee and Iroquois counties, south of Hersher. Some of these reach a height of about 75 feet. At the point where the course of the moraine changes from east of north to southeastward, near Ste. Anne, there is a very prominent group of knolls, called Mount Langum, standing 75 to 100 feet above bordering tracts on the north. These groups of prominent knolls have, however, a combined area of but a few square miles. Toward the inner border throughout the entire length of the moraine the swells gradually decrease in height and become less frequent, until they can not be distinguished from the gentle undulations of the till plain, which are commonly 5 or 6 feet in height. In a few places, aside from those noted above, a somewhat sharp knob-and-basin topography is developed. The most conspicuous development is in Kendall County along the sharp crest, and this type of topography is characteristic of much of the crest in that county. The knobs seldom exceed 25 feet in height; but as they cover only 2 or 3 acres each, they are much sharper than the majority of the knolls. The basins are shallow, saucer-like depressions. It is worthy of note that the portions of the moraine having sharpest expression are usually covered with forest. Possibly the protection afforded by forest growth is partially responsible for the sharper contours, but it seems hardly probable that the difference in contour in forest and prairie can be entirely due to this protection.

The outer margin of the moraine often extends out in spur-like projections a mile or more beyond a regular border, and usually where streams emerge the margin is indented an equal or even greater amount. These spurs slope down much less abruptly from the morainic crest than the tracts between them, thus giving the appearance of low ridges running out from the crest nearly at right angles to its course. The indentations at the places where streams emerge are not referable to erosion by the present streams, but are in all probability due to the removal of material by streams issuing from the ice sheet.

There are occasional breaks or narrow gaps interrupting the crest. One about 4 miles east of Yorkville, about 75 feet in depth and one-fourth to one-half mile in width, passes entirely across the moraine, permitting drainage from the inner-border plain to pass through the moraine to Fox River. Another gap fully as large is found in the southwest corner of

Kendall County and is represented on the Marseilles topographic sheet. A water parting occurs in this valley-like gap at the inner border of the moraine near the line of Grundy and Kendall counties. It stands only 640 feet above tide, while neighboring portions of the moraine on the north and west are about 100 feet higher. About 6 miles southwest from this gap there is a shallower one in which the water parting is 690 feet, or 40 to 60 feet below neighboring portions of the morainic crest. At the Illinois Valley the moraine is interrupted by a gap about 1½ miles in width. It stands 675 to 700 feet above tide at the south bluff and 650 to 675 feet at the north bluff. The broad bottom of the valley stands only about 500 feet; but this, as shown below, has been lowered by the "Chicago Outlet." These gaps, like the indentations, seem referable to streams issuing from the ice sheet during the formation of the moraine, and perhaps also during the withdrawal of the ice from the plain on the east.

In eastern Livingston and northern Ford counties the main ridge lies near the north border of the belt. Outside of it, extending nearly to the east fork of Vermilion River (a distance of about 6 miles), there is an undulatory tract probably of morainic character. The surface of much of this tract is fully as undulatory as on the main part of the moraine, and stands nearly as high as the crest of the moraine. Plane tracts one-half mile to a mile or more in width and 25 to 40 feet in depth extend north from the east fork of Vermilion River nearly to the crest of the moraine, greatly interrupting the continuity of the undulatory tract just noted and giving the appearance of spurs leading out to the south. There is, however, at the east a well-defined crest in this outer belt with a trend approximately parallel with that of the main crest. This suggests the interpretation that the moraine consists of a double ridge in this region, and that its outer ridge has been imperfectly developed or greatly eroded. If the imperfection is due to erosion, it seems necessary to restrict the eroding agency chiefly to water escaping from the ice sheet, for there has been apparently but little postglacial erosion in this locality.

THICKNESS OF THE DRIFT.

The thickness of the drift along the Marseilles moraine has a known range from less than 100 feet up to 360 feet. In eastern Kane and western Dupage counties the thickness along the crest is generally 100 to 150 feet.

In Kendall County it has a known range from 100 feet to fully 200 feet. In Lasalle County the well records show a range from about 100 up to 285 feet. In Livingston County the range is still greater, the distance to rock varying from 100 to 360 feet. Along the line of Kankakee and Iroquois counties it decreases from about 160 feet at the west to only 60 feet at Ste. Anne, but wells between Ste. Anne and the State line penetrate 80 to 150 feet of drift.

The greater part of the drift appears to be referable to the Wisconsin drift sheets. The older sheets are seldom entered at less than 100 feet along the crest of the moraine, and in some wells a fresh-looking drift (Wisconsin) is reported to extend to a depth of 160 feet. The drift referable to the invasion which formed the Marseilles moraine probably about equals in thickness the measure of the relief of the moraine, which, as noted above, is 50 to 125 feet.

STRUCTURE OF THE DRIFT.

The Marseilles moraine consists mainly of a sheet of blue till which contains only a moderate amount of coarse rock materials. A few low gravelly knolls occur in some of the recesses on the outer border of the moraine in Kane, Kendall, and northern Lasalle counties. The sharp knolls south of Hersher, and the prominent group of knolls known as Mount Langum, near Ste. Anne, are composed largely of gravelly material. These constitute the chief instances of the occurrence of gravelly knolls along the entire length of the belt. There are often small pockets or thin beds of sand and gravel inclosed in the sheet of till, which afford a supply of water for the shallow wells. These seldom afford a sufficient amount of water for dairying or stock raising, the supply for these purposes being obtained either from the older sheets of drift or from the underlying rock.

This moraine carries very few surface bowlders, there being scarcely enough to supply the needs of the residents for foundations of buildings and construction of bridge culverts. In one locality, however, east of Yorkville, the moraine is crossed by a bowlder belt which apparently pertains to a later advance of the ice, since the bowlder belt does not follow the moraine but passes southward across the inner-border plain, as indicated later (pp. 325–326).

The depth of surface oxidation in this moraine is less than on any other moraine of the Wisconsin series within the area under discussion. In Livingston County the blue till is commonly entered at 4 to 6 feet, and in places at even less depth. The oxidized till, therefore, has scarcely half the depth usually found in the Wisconsin drift sheets. The slight depth of surface oxidation is probably attributable to the compactness of the till, which is nearly impervious to water. It can not be attributed to flatness of surface, because the depth of oxidation is found to be very slight on undulating as well as level portions of this drift sheet.

The sections of many wells obtained along this moraine and on the inner border are presented in the discussion of wells (Chapter XIV) in the counties traversed by the moraine. These serve to indicate the great preponderance of till over assorted material in the portion of the drift referable to the Marseilles moraine. They also serve to indicate the relative proportions of till and assorted material in the sheets of older drift underlying the Marseilles and other Wisconsin drift sheets.

CHARACTER OF THE OUTWASH.

Along Fox River, in Kane and Kendall counties, just outside the Marseilles moraine, there is a belt of coarse gravel. In places the deposit lies mainly on the same side of the river as the moraine, but generally it is on the opposite side. At Batavia it is chiefly on the west side, at Aurora on the east side, and at Yorkville on the west side. At Millbrook and at Millington the larger part of the gravel is on the east side of the river. The belt of gravel extends but a short distance below Millington, the valley below that point being cut in till and rock strata. The origin of this belt of gravel has not been decided. Possibly it is referable to the invasion which formed the Marseilles moraine, but quite as probably it should be referred to the later advances of the ice sheet, during which the Marseilles moraine was partially overridden. The gravel is so extensive in Kane and Kendall counties and so small in amount farther down Fox River as to suggest the interpretation that it forms an extensive delta in northern Kendall and southern Kane counties, and that free drainage or escape of the waters down Fox River had not been established.

In the vicinity of the Illinois River there are indications of a lake-like expansion of outflowing waters whose borders are found in the sand ridges

discussed on a preceding page (p. 288). The Illinois Valley, therefore, appears to have been unopened along the section between the Marseilles moraine and the inner moraine of the Bloomington series.

In eastern Illinois the basin now drained by the Iroquois River northward to the Kankakee would have been prevented from discharging in this direction by the ice sheet. It is probable, as noted above, that the outlet from this district was westward across the rim of the basin in northern Ford County to the east fork of Vermilion River. As this rim stands somewhat higher than the northern part of the basin, it may be supposed that the ice sheet terminated in a shallow body of water. The only outwash found along the outer borders of the moraine in this district consists of fine sand and silt forming a thin coating on the surface of the till. Whether this is an outwash from the ice at the time of the formation of the Marseilles moraine or is of later date can scarcely be determined in the present stage of investigation. Studies in western Indiana indicate that a lake may have occupied this region for some time subsequent to the retreat of the ice from the Marseilles moraine, and this silt-and-sand deposit may be a product of the later stage of the lake.

In eastern Livingston County there may have been a fair escape for the water southward into the East Fork of Vermilion, though this is not fully demonstrated.

Reviewing the above statements, it appears that, with the possible exception of the northern portion of the moraine in Kane and northern Kendall counties, the ice sheet was bordered extensively by lakes, which prevented a vigorous outwash. But these lakes were so shallow as to interfere in no way with the building up of a bulky moraine. They seem also to have allowed the waters escaping from the ice sheet to form the gaps and indentations in the moraine, noted above. If these were formed either by water escaping from the ice while it overhung the ridge, or at a later date from a lake held on the east side of the ridge (the only probable agencies yet recognized), the existence of lakes in the outer border district may seem questionable. This seeming incompatibility may perhaps be explained by assuming that a submarginal glacial stream had accumulated sufficient hydrostatic pressure to carry a strong current into the extra-marginal lakes.

INNER-BORDER TILL PLAIN.

On the inner border of the Marseilles moraine from northern Kendall County, where it separates from the Minooka Ridge, southward through Grundy and adjoining portions of Lasalle and Livingston counties, and thence eastward through Kankakee County, there is a till plain which shows a perceptible descent away from and nearly at right angles to the moraine. As the moraine describes nearly a half circle in this interval, the sloping plain converges toward a focal point, which is located near the head of the Illinois River. There is a similar descent toward the head of the Illinois from the east; thus a basin is formed, which is commonly known as the Morris Basin, from the city of Morris, which stands near its central portion. The slopes of this plain are well shown by the direction of drainage lines, which converge from all quarters toward the head of the Illinois River. (See topographic map, Pl. III.) At present the basin is deeply notched at its western border by the valley of the Illinois River, but at the withdrawal of the ice sheet the evidence is quite clear that the western rim stood sufficiently high to hold a lake of considerable size in the Morris Basin. The history of this lake is discussed in some detail below.

On the border of this till plain next to the moraine the surface is gently undulating, but within a few miles it become an almost expressionless plain. In Kankakee, southwestern Will, and eastern Grundy counties the plain is occupied by sand dunes and beaches; elsewhere it is generally very smooth. There are, however, a few points in southeastern Kendall and northeastern Grundy counties where the drift is slightly ridged.

In the vicinity of Lisbon, in southern Kendall County, the drift is insufficient to conceal the inequalities of the limestone ridges, but the surface is only gently rolling, the crests of the ridges being scarcely more than 20 feet above the sags. This area is 2 to 2½ miles from north to south and 5 to 6 miles from east to west, and lies mainly in the south half of T. 35, R. 7 E.

The drift along the border of the Marseilles moraine has generally a thickness of 100 feet or more, but upon descending the slope toward the head of the Illinois the thickness decreases, and there are extensive areas in eastern Grundy, southwestern Will, and northern Kankakee counties where rock is encountered at very slight depth, so that the shallow ravines

and shallow wells and even the cellar bottoms reach it. The drift appears to be composed mainly of till and differs in no essential degree from that found in the Marseilles moraine. The yellow or oxidized till at surface is apparently somewhat thicker than on the moraine. At the surface there are extensive deposits of sand and silt occurring up to an altitude of nearly 650 feet, though most abundant at 575 feet or less, which in all probability are referable to the lake that occupied the basin. These deposits in some places reach considerable depth and are either accumulated in knolls and ridges or spread evenly over the surface. In other places they are insufficient to conceal the surface bowlders.

In the greater part of this district wells may be obtained at a depth of 25 feet or less. In some cases they are obtained at the base of the surface sand; in others near the junction of the yellow and blue tills, there being not infrequently thin beds of sand and gravel at that horizon; in still other cases they enter the blue till. Several flowing wells have been obtained from the drift. These are discussed in connection with other wells, in the detailed discussion of wells given in Chapter XIV.

CHAPTER X.

THE LATE WISCONSIN DRIFT SHEETS.

BASIS FOR SEPARATION FROM THE EARLY WISCONSIN.

The necessity for separating the moraines of this later drift into two series was brought out by Chamberlin's early studies in eastern Illinois and western Indiana. He discovered that the very bowldery morainic belts of Benton and Warren counties, Indiana, pass directly across the line of the earlier moraines which lead up to them from the west. The fact was also noted that the earlier series of moraines are not markedly older than the later series. In view of this freshness of the drift of the earlier series and of certain obscure tracts in the Kankakee Basin, he makes the following statement:[1]

The drift of this area [Kankakee Basin] bears undoubted evidence of being recent, and, though this is in considerable part due, superficially, to aqueous agencies, it seems to me probable that the region will prove to have been largely, possibly completely, covered by ice in the earliest stage of the second glacial epoch. It is not, however, traversed by conspicuous moraines, at least not by any as well developed as those outlined. Low-ridged belts of subdued morainic aspect have been observed at numerous points, but their relations have not yet been traced out.

A similar qualifying remark may here be made concerning a considerable area in northern Illinois, outside the moraine described in this paper. The freshness of its drift and the unsculptured contour of its surface bear evidence of recent origin.

Subsequent studies by Chamberlin and his associates have brought out more clearly the evidence that the bowldery moraines are out of harmony in trend with the moraines of the early Wisconsin series. They have also shown that the bowldery moraines present a somewhat fresher surface contour than the moraines overridden by them. It is upon the basis of these differences in trend and in freshness of contour that the removal from the early Wisconsin has been made. As yet no soil or leached or weathered zone has been found separating the drift of the two series, and it still seems

[1] Third Annual Report U. S. Geol. Survey, p. 331.

questionable whether the interval between their deposition was sufficiently long to justify their reference to distinct glacial stages. The shifting of the ice lobes, however, is thought to indicate a retreat of some consequence between the two ice advances—a retreat probably much greater than took place between the formation of neighboring moraines of the early Wisconsin series.

OUTLINE OF THE LATE WISCONSIN BORDER.

So far as is yet known, the oldest moraine of the late Wisconsin series is the Iroquois moraine of the coalesced Erie-Saginaw lobe. Full correlations, however, have not been made of moraines of this series in the several ice lobes. This moraine appears in northwestern Pulaski County, Indiana, in the midst of the sand area known as "Old Lake Kankakee," and leads southwestward along the divide between the Iroquois and Kankakee rivers, across Jasper and Newton counties, Indiana, to eastern Iroquois County, Illinois. It there swings abruptly southward, crossing the Iroquois River between the State line and Watseka, Illinois, and soon curves to the southeast, reentering Indiana in northwestern Benton County. It thence passes southeastward across Benton and Warren counties, coming to the Wabash Valley at Williamsport. Its further continuation to the southeast is indicated approximately on the map accompanying Professor Chamberlin's paper in the Third Annual Report. The moraine is discussed in detail in a report now in preparation, which embraces the moraines of the Erie lobe.

From the point where the Iroquois moraine turns southward in eastern Iroquois County, Illinois, a bowldery belt leads northwestward past Ste. Anne to the Kankakee River just above the city of Kankakee, being closely associated with the Marseilles moraine to that point, but apparently distinct from it at points farther north and west. This belt is discussed below as a possible correlative of the Iroquois moraine. By this interpretation the moraine occupying the divide between the Iroquois and Kankakee rivers in Newton and Jasper counties, Indiana, is interlobate in character. This interpretation would furnish an explanation for the abrupt eastern termination of the moraine, there being a coalescence of the lobes so complete in the eastern part of the Kankakee Basin that no moraine was formed. Unfortunately, the features are somewhat vague in the district northwest from the point where the Iroquois moraine turns south and the interpretation

is not entirely beyond question. There seem, however, sufficient grounds for referring certain features in that region provisionally to the late Wisconsin deposits. These features are of two classes, namely, bowlder belts and ridged drift. These are discussed separately, since their association is not sufficiently close to make it certain that they represent a single ice advance. As indicated below, the ridging (discussed under the head "Minooka Till Ridge") may have preceded rather than accompanied the deposition of the bowlders.

SECTION I. THE MINOOKA TILL RIDGE.

DISTRIBUTION.

This till ridge receives its name from the village of Minooka, in northeastern Grundy County, which is situated on its crest. As noted above, it is united with the Marseilles moraine in Kane County, and being smaller than that moraine its discrimination may be made with difficulty. In the northeast part of Kendall County it leaves the Marseilles moraine and takes a southward course along the county line between Kendall and Will and Grundy and Will counties to the head of the Illinois River. The crest as a rule lies in the eastern tier of sections in Kendall and Grundy counties, but in places touches western Will County. The width of the ridge, including both slopes, is scarcely 2 miles. It consists of a single smooth ridge on whose crest and slopes there are few swells exceeding 10 feet in height. The ridge is crossed by two valley-like depressions which unite near its western edge in sec. 13, T. 36, R. 8 E., and drain west into Au Sable Creek. These are cut down to the level of the plain on the east side of the ridge. They apparently were formed by the discharge of water from the ice margin or ponded between the ridge and the receding ice front.

PROBABLE LINE OF CONTINUATION.

Up the Kankakee River, from the head of the Illinois nearly to the State line, there is an occasional development of low drift ridges and gentle swells on the north side of the valley. On that side of the river, 1 to 3 miles back from the stream, there is an abrupt bluff-like rise of 25 to 50 feet, and the ridges and swells front this bluff or lie immediately back of it. This system of ridges and swells nearly everywhere stands slightly higher than the plain which lies to the north. In the vicinity of Kankakee this

ridged belt borders the river quite closely and part of the city stands on it. From that city it takes a course slightly north of east to Exline, cutting across the great bend in the river opposite the mouth of the Iroquois River. Some uncertainty is felt as to its continuation from this point. It may continue eastward into Indiana parallel to the river and pass beneath the Valparaiso moraine, though it seems quite as probable that it finds its continuation in the belt leading southeast from Mount Langum, above described (see Marseilles moraine). The break opposite Mount Langum is merely the width of the Kankakee Valley, scarcely 2 miles.

No similar ridging occurs on the south side of the river in western Kankakee or in Will County. There is instead a gradual rise from the low bank of the river southward through a sand-covered district to the till plain which lies inside the Marseilles moraine. The greater accumulation of drift on the north side of the river, taken in connection with the occasional development of moraine-like features, apparently supports the interpretation thus made—that the continuation of the Minooka till ridge may be found along this line.

RELIEF.

The southern end of the well-defined Minooka Ridge (at the head of the Illinois River) stands 100 to 110 feet above the Illinois River. The general relief of this ridge above the plain which borders it on the west is 50 to 70 feet. The profile of the Chicago, Rock Island and Pacific Railroad, which crosses the ridge at Minooka, shows a relief on the west side of about 65 feet. The relief is slightly less on the east and is also less abrupt than on the west.

The bluff-like ridge along the Kankakee, where best developed, stands but 30 to 40 feet above the plains on the north, and its usual relief on that side is only 10 to 20 feet. On the side next the Kankakee there is a general relief of 30 feet or more, with occasional points where it exceeds 50 feet. Evidently a portion of this relief is due to stream erosion, but the excavation is so shallow that the stream is responsible for scarcely 20 feet of the relief.

THICKNESS OF DRIFT.

Beneath the crest of the Minooka Ridge, from the head of the Illinois northward, the drift is shown by wells to be 130 to 150 feet and in one

instance nearly 200 feet in thickness, the thickness as compared with that on bordering plains being about as much greater as the measure of the relief of the ridge. In the portion along the Kankakee the thickness seldom exceeds 60 feet, but is greater along the higher parts than on the lower or than on the border plain, as would be expected from the relief which it presents.

STRUCTURE OF DRIFT.

In the ridge north from the head of the Illinois the surface portion of the drift to a depth of 8 to 12 feet consists of a yellow till containing many pebbles. It is sandy in places, but as a rule is a stiff, sticky clay, very slowly pervious to water.

This yellow till is underlain by a grayish blue till containing occasional gravel or sand veins, which furnish water in small quantities. This bed of till often has a thickness of 100 feet or more. Beneath it there is in places a heavy deposit of sand. This may not underlie the whole of the ridge, but has been penetrated in several wells along the crest in Kendall County. It furnishes abundance of water for wells.

The ridge from Minooka northward carries a black surface soil several inches in depth, such as is found on the bordering plains. There are few surface bowlders, and pebbles are rare within 18 inches of the surface.

The drift along the north border of the Kankakee is mainly till, and surface bowlders are more abundant than in the portion north of the head of the Illinois River.

CHARACTER OF THE OUTWASH.

The well-defined portion of the Minooka Ridge has a low part of the Morris Basin on its outer border. Unless the outlet down the Illinois had been opened to a level as low as this part of the basin, the basin would have held a lake, and there scarcely could have been vigorous discharge from the Minooka Ridge. Terraces on the Des Plaines River which have their head in the Valparaiso moraine and were formed in connection with that moraine indicate that a lake stood in this basin at the head of the Illinois while they were forming and that its level was about 560 feet above tide, or 60 feet above the present head of the Illinois River. This lake level is well defined also by beaches which are to be seen both north and south of the Illinois.

Such being the case at the time the Valparaiso moraine was forming, it follows that at the time the Minooka Ridge was formed the lake stood fully as high, if not higher, for the Minooka Ridge antedated the the Valparaiso moraine in its formation. The low part of the basin immediately west of the Minooka Ridge stands only a few feet above the level of the beaches referred to and would apparently have been extensively inundated during the melting of the ice sheet, even if the outlet from the Morris Basin had been cut down to the level of the well-defined beach bordering the Illinois River. A vigorous discharge of waters across the basin could scarcely be expected. Certain features which suggest vigorous discharge will next be considered.

The channels noted above, which cross the ridge a few miles north of the head of the Illinois, seem to have been made by a stream with a current having considerable volume, if not considerable strength. They are cut down to a gradient too low to give the present small stream which drains them a good gradient, and are consequently occupied by marshes. The conditions under which they were formed were probably similar to those which caused the gaps in the Marseilles moraine discussed above (pp. 310, 314). A thin coating of sand is found in the portion of the basin immediately west and south of these channels, a feature which implies current action, but perhaps no stronger than is consistent with the presence of a lake or very broad lake-like stream. On the whole, the evidence seems insufficient to establish the existence of good drainage conditions.

Turning to the Kankakee for light as to drainage conditions accompanying the formation of the ridge on its north border, it is found that sand deposits occur along the opposite side of the valley, forming a much more conspicuous feature than on the west border of the Minooka Ridge. The deposits extend back usually 3 or 4 miles from the present stream and reach an elevation fully as high as the ridge on the north side of the valley. They have been drifted in places into prominent dunes. This sand may be interpreted either as the direct outwash from the ice at the time the ridged belt north of the valley was in process of formation, or it may seem referable to subsequent stream transportation, for the Kankakee Valley was the line of discharge for glacial streams issuing from the Saginaw lobe during the period embraced in the formation of two or more strong moraines, and from a part of the Lake Michigan lobe during the formation of the Val-

paraiso moraine. These glacial streams had a current sufficiently strong to excavate a channel throughout nearly the entire length of the Kankakee Basin, whose north bluff may still be seen rising 15 to 30 feet above the Kankakee marsh. A current of this strength would seem to be entirely adequate to cause the transportation of such sand deposits as are found on the lower course of the Kankakee. It may be questioned, therefore, whether these deposits may be referred with certainty to streams issuing from the ice sheet at the time the Minooka Ridge was in process of formation. The evidence here, as in the case of the channels north of the Illinois Valley, is scarcely sufficient to establish the occurrence of good drainage conditions at that time. The peculiar association of this sand belt with a bowlder belt is discussed below (p. 326).

Inasmuch as the Iroquois moraine appears to have been formed either contemporaneously with or subsequent to the Minooka Ridge, the character of its outwash may be found serviceable in drawing conclusions concerning the outwash from the Minooka Ridge.

On the outer border of the Iroquois moraine in Iroquois County, Illinois, and also in Benton County, Indiana, the outwash is a fine sand which has been transported to the lower parts of the Iroquois Basin and down the valley of Sugar Creek, a southern tributary of the Iroquois. As this outwash is in a district lying outside the line of discharge for the glacial streams which traverse the Kankakee Valley, it is less difficult to interpret than the sands of the lower Kankakee. Its position is such as to be favorable for discharge of water if no lake were present, since there is a descent away from the outer border of the moraine. Yet the fineness of the material seems to indicate that very imperfect drainage conditions attended the deposition of this moraine. The feebleness of discharge is thought to indicate that lake-like conditions may still have persisted not only in the Morris Basin but also in the Kankakee and Iroquois basins.

On the outer border of the combined Marseilles and Minooka moraines, in northern Kendall and southern Kane counties, there is an extensive gravelly plain, to which attention was called in connection with the Marseilles moraine. This plain has not as yet been definitely connected with any of the moraines of the late Wisconsin series. Three means of deposition need to be considered, as follows: (1) By streams flowing down the Fox River Valley during the formation of the Valparaiso moraine and

spreading out a delta similar to that formed in the lower part of the Des Plaines Valley by streams issuing from the same moraine; (2) by streams issuing from the ice at the time the Minooka Ridge was forming, for the ice at that time seems to have extended as far, at least, as the western edge of the Marseilles moraine in Kane County; (3) by outwash from the Marseilles moraine, which sweeps around the eastern and southern border of the plain. In the present state of knowledge it seems difficult to draw inferences concerning the date at which this plain was formed, and also concerning the broader question of the character of the outwash from the ice sheet during the Minooka substage of glaciation.

Whether the Minooka Ridge is to be included in the late Wisconsin series can not perhaps be decided at the present stage of investigation. If it can be clearly established that during the interval between the formation of the Marseilles moraine and the Minooka Ridge the outlet down the Illinois had been lowered from about 640 feet above tide (the level of neighboring outlets through the Marseilles moraine) to a level nearly as low as the 560-foot beach bordering the Illinois in the Morris Basin, a correspondingly late date for that ridge may be assumed. But at present there is much uncertainty as to the amount of work accomplished by that outlet prior to the formation of the Minooka till ridge. The bearing of bowlder belts on this question is considered below (p. 327.)

INNER-BORDER TILL PLAIN.

On the inner border of the Minooka Ridge, from the vicinity of Elgin southward to the head of the Illinois, there is a narrow till plain nowhere more than 6 miles, and usually but 2 or 3 miles, in width, which separates this till ridge from the Valparaiso morainic system. North from Elgin the Minooka Ridge has not been separated from the Valparaiso system. From the head of the Illinois eastward along the north side of the Kankakee Valley there is a similar till plain separating the ridged drift on the border of the valley from the Valparaiso morainic system. Its width is greatest on the meridian of Kankakee, where it is fully 12 miles, the usual width being only 7 or 8 miles. East from Kankakee the till plain north of the river decreases in width and extends only a short distance east of the State line. The Valparaiso system there comes to the border of the Kankakee marsh.

An extensive sand-covered tract south of the Kankakee, in western Indiana and the east border of Illinois, is discussed below.

The portion of the till plain north of the head of the Illinois shows usually a perceptible descent away from the Minooka Ridge, accompanied by a corresponding decrease in the thickness of the drift. On the borders of the ridge the drift is 100 feet or more in average depth, while at the east border of the till plain next to the Valparaiso system it is in places but 20 to 30 feet in depth. The drift appears to be mainly soft till, referable to the Wisconsin sheets. In places it is gravelly or sandy at base.

The portion of the till plain north of the Kankakee in general rises slightly toward the north. The drift is apparently only 30 to 40 feet in average depth. In places rock ridges which carry scarcely any drift rise slightly above the general level of the plain. Such ridges may be seen near Manteno. The drift is apparently nearly all Wisconsin. A few instances of the penetration of a buried soil in wells were reported from the northeast part of Kankakee County. This soil is within a few feet of the bottom of the glacial drift. The drift north of the Kankakee contains much sand and gravel, but there is usually a capping of till a few feet in depth. The well sections of Will and Kankakee counties, presented in the latter part of this report, will set forth the variations in the structure and the thickness of the drift.

SECTION II. BOWLDER BELTS.

The Marseilles moraine and also the Minooka Ridge, as already indicated, carry a very few bowlders on the surface. Bowlders are also comparatively rare on the inner or eastern slope of these ridges and on the till plain between the Kankakee River and the Valparaiso moraine. There is, however, a strip on the borders of the sand area along the south side of the Kankakee in Kankakee and Will counties, and in places within the sand area, where bowlders abound. This belt may connect on the southeast with the Iroquois moraine, though the connection is rather obscure because of sand accumulations. It appears to find a continuation northwestward in Grundy County along the borders of Mazon Creek, from the vicinity of Gardner to the mouth of the stream near Morris. From Morris a belt of bowlders extends northward 3 or 4 miles, beyond which, for about 6 miles, they are comparatively rare. Near Plattville a narrow belt sets in,

which leads northward to the Marseilles moraine and passes over that moraine, as already noted, in the vicinity of the valley-like gap east of Yorkville. The bowlders occupy the gap and also the portion of the moraine to the east. To the north from this point the broad gravel plain along Fox River interrupts the belt for a space of 3 or 4 miles, but at the north border of this gravel plain bowlders again become numerous and abound along the west side of Fox River throughout the interval between this gravel plain and the composite belt of moraines above described.

The bowlders are unevenly distributed, there being small tracts and narrow strips where they are so numerous as to constitute a serious obstruction to the cultivation of the soil, occasionally numbering several hundred per acre, but throughout most of the belts there are only a few per acre. The belt taken as a whole probably carries ten times the number of bowlders found in neighboring districts.

The sand along the south border of the Kankakee is usually so heavy that the bowlders, if present, would be obscured. In places where the sand is thin, bowlders are usually abundant. These oasis-like tracts in the midst of the sand area are in some cases difficult to account for. The heaping of the sand into ridges is probably due, in part at least, to wind action, and the wind may also have been influential in sweeping the sand away from parts of the surface. It seems well, however, to introduce an alternative or supplementary explanation, though the applicability has not been fully tested. By the alternative interpretation a causal relationship is suggested between the occurrence of bowlders and the absence of sand, and the explanation found in the persistence of ice where the bowlders occur until the sand had accumulated in practically its present depth and topography. This alternative explanation would also make the ridging of the sand partly the result of glacial molding which has been intensified by subsequent æolian action. This interpretation has been suggested by features found in the old Lake Kankakee district, discussed below.

It should perhaps be stated that the bowlders here or elsewhere in the belt can scarcely be considered a residue from erosion of the till, for they often occur on plains where there has been scarcely any opportunity for erosion. Furthermore, they differ in constitution from the coarse rocks of the till, being almost wholly of crystalline rocks of distant derivation, while the till abounds in local rock fragments, both coarse and fine.

It seems more probable that the belt marks the position of the ice margin at some stage of advance between the formation of the Marseilles and Valparaiso moraines. Were the belt accompanied throughout by a moraine, or even a thin sheet of drift, this interpretation would seem well supported. For a few miles in the vicinity of the point where it crosses the Marseilles moraine there are low knolls accompanying the bowlders which may prove to be of the same date as the bowlder deposition. They are much smaller than the swells on the Marseilles moraine, being usually only 3 to 5 feet in height and covering a few square rods each. They inclose shallow saucer-like depressions, and on the whole give the surface a fresher contour than is presented by the portion of the Marseilles moraine to the west. The portion of the belt from Morris northward was made a subject of joint investigation by Professor Chamberlin and the writer, and to each of us the surface contours appeared somewhat fresher along the line of the bowlder belt than in the district to the west. But the development of a new or distinct topography in connection with the bowlder belt seems at best to be limited to the immediate vicinity of the Marseilles moraine, and leads us to feel some doubt concerning the interpretation of the occurrence of a thin sheet of drift in connection with the bowlder belt.

It will be observed that the course of this bowldery strip is nearly parallel with the Minooka Ridge and its supposed eastern continuation along the Kankakee. This parallelism has suggested the interpretation that the bowlder belt may be closely related to that ridge Possibly there was a temporary advance of the ice beyond the position it held while forming the ridge, or possibly the accumulation of the bowlders and the ridge occurred at the same time, the former being at the extreme margin and the latter a short distance back from the margin. The smoothness of the ridge apparently favors the interpretation that it is a submarginal accumulation.

Another interpretation refers the formation of the bowldery strip to an advance subsequent to the formation of the Minooka Ridge. In that case the smoothness of the ridge may be due to its having been overridden.

It seems highly probable that this bowldery strip is to be correlated with the Iroquois moraine and associated bowlder belts found in Iroquois County, Illinois, and Benton and Warren counties, Indiana, which are referred to the late Wisconsin invasion. The indefiniteness of the bowldery strip in the sandy districts of eastern Kankakee and northeastern Iroquois

counties prevents a full and satisfactory correlation. But nothing to oppose the correlation has yet been discovered. At present it seems necessary to leave unsettled both its relation to the Iroquois moraine and to Minooka Ridge.

SECTION III. LAKE KANKAKEE.

Nearly thirty years ago Mr. F. H. Bradley applied the name Lake Kankakee to a body of water which he thought formerly occupied a large part of the Kankakee drainage basin.[1] The existence of a lake in this region was suggested by the occurrence of deposits of sand outside the limits of the present Kankakee marsh. Mr. Bradley recognized the influence of wind in distributing sand over areas not covered by the lake, but considered the evidence satisfactory that along the line of the Louisville, New Albany and Chicago Railroad lake water had reached an elevation about 685 feet above tide. He had not full opportunity to explore the region; hence his outline of the extent of the lake is rather indefinite.

Chamberlin touched briefly upon this sand area in his paper in the Third Annual Report, as follows:[2]

> These dunes are a portion of a somewhat extensive tract, or perhaps rather a series of tracts, in northwestern Indiana, the precise distribution and origin of which are yet undetermined. They lie mainly in the Kankakee Basin, which was formerly occupied by an extensive lake or lacustral river—"Old Lake Kankakee" of Bradley—and have been thought to be its shore accumulations; but their very wide extent and great mass relative to the lake area, as well as certain features of their known distribution, throw doubt upon the adequacy of this explanation. It would seem, from a consideration of the glacial distribution of the second epoch, that this region must have been the avenue of discharge of vast quantities of water, shed from the adjacent slopes of the great glaciers occupying the basins of Lakes Michigan, Huron, and western Erie. The great accumulations of sand probably had their ulterior origin in this exceptional drainage, and were subsequently modified by lacustrine, fluvial, and æolian action. Their history is one of much interest, and its satisfactory determination can scarcely fail to reward industrious investigation when pursued in the light of the glacial phenomena now under consideration, and may, in turn, cast reflex light upon them. But however that may be, for the present, these dunes interpose an element of uncertainty in the tracing of the moraine at what would, in any event, be a critical portion of its course, for it is impossible to determine the character of the drift which they conceal.

The extent of the sand in the Kankakee Basin and in districts to the south has been further investigated by Chamberlin since the above was

[1] Geology of Illinois, Vol. IV, 1870, pp. 226–229.
[2] Third Annual Report, U. S. Geol. Survey, 1881–82, 1883, pp. 330–331.

written, as well as by Prof. A. H. Purdue and the writer. The limits have been determined with considerable accuracy, and the general features of the area have also been studied. The phenomena, as will be seen, are of a peculiarly puzzling nature, and as yet a fully satisfactory interpretation of them has not been reached.

EXTENT OF THE SAND.

Beginning at the northeast and passing southward, the sand is found to have its eastern limit at the border of the Maxinkuckee moraine of the Saginaw ice lobe in western Marshall County, Indiana (see Pl. VI). A few dunes occur on the moraine, but the continuous sand follows approximately the west border. Farther north, in St. Joseph County, a gravel plain occupies the outer or west border of the Maxinkuckee moraine. The moraine swings eastward along the north side of Tippecanoe River in northern Fulton County, and a narrow sandy belt extends up the Tippecanoe Valley along the outer border of this moraine as far as Rochester, but the east border of the main sand area continues southward through western Fulton County and northwestern Cass County to the vicinity of Lake Cicott. Purdue reports that for about 9 miles north of Lake Cicott a well-defined sand ridge forms the east border of the till plain that descends westward to the Tippecanoe River. This ridge turns abruptly westward near Lake Cicott and is nearly continuous to the Tippecanoe Valley at Monticello. For a part of this course the ridge lies along the north slope of a moraine of the Erie lobe. After crossing Tippecanoe River at Monticello the moraine turns south, while the ridge continues in a course slightly south of west about to the line of White and Benton counties. From this point a narrow sand ridge has been traced by Purdue in a course north of west nearly to Kentland, Indiana. There is, however, very little sand on the surface for several miles north from this ridge, and he did not succeed in tracing the ridge farther west.

Purdue reports that there is a somewhat broken east-to-west sand ridge north of Indian Creek in southeastern Pulaski County, which passes through the village of Rosedale (Oak post-office), where it presents large dunes, and thence turning northeastward, terminates at a gravelly knoll in the northeast corner of T. 29, R. 1 W. The area from this ridge north to and beyond the middle of Tippecanoe Township is an extensive sandy plain, with the

exception of some short ridges of sand. There are also the following areas within this plain where sand is not present: (1) A small area in eastern Pulaski County, 1½ miles north of Bruce's Lake; (2) an area south of Bruce's Lake extending south to Little Mill Creek and west about 3 miles from the county line; (3) between Mill Creek and Little Mill Creek; (4) a small area about Star City. This ridge has an altitude nearly as great as that of the ridge south of it, but its relation to that ridge and to the border of the sand area was not clearly worked out.

Another narrow sand ridge was traced by Purdue from Monon Creek, about 5 miles southwest of the village of Monon, nearly directly west for about 20 miles to Percy Junction in Newton County. This ridge constitutes the south border of the main sand area in Jasper County. West and northwest from the western end of this ridge there are a few low sand ridges, but these occupy only a small part of the surface and do not have definite connection with each other nor with the long ridge just mentioned. There is enough surface sand, however, to indicate that that region was covered by a body of water. The Iroquois moraine, on the north side of the Iroquois River, appears to have been partially submerged, but its highest parts probably rose above the water and shut in a bay on the south, in which wave action was not sufficiently strong to form heavy sand deposits.

The south border of the main sand area follows the north slope of the moraine westward into Iroquois County, Illinois, and there swings southward with the Iroquois moraine to Coon Creek, in southwestern Sheldon Township, forming apparently an outwash apron, as noted above.

A belt of dunes leads westward from this sand area across Belmont and Crescent townships. There is considerable surface sand from this belt of dunes northward, but to the west and northwest only occasional low sandy ridges and thin patches of sand are found. A sand ridge, as noted on a previous page, passes westward from the southwest part of the main sand area in central Iroquois County through Onarga and Ridgeville to the east fork of Vermilion River, through which there was probably a temporary westward outlet to the Vermilion Basin, and thence to the Illinois. Possibly this sand ridge and the belt of dunes with which it connects at the east are independent of the sand bordering the Iroquois moraine.

The west border of the Iroquois sand area follows nearly the north flowing part of Iroquois River northward to northern Iroquois County, and there swings eastward along Beaver Creek Valley, crossing the Marseilles moraine between St. Anne and St. Mary, and thence extending both eastward and westward into the Kankakee Basin.

As noted above, the sand is continuous along the south border of the Kankakee to Grundy County, and thence westward along the Illinois to the borders of the Marseilles moraine. The north border of the sand follows the low bluff on the north side of the Kankakee from Will County, Illinois, eastward to the head of the Kankakee, where the tracing began.

It will be observed that this sand-covered district occupies not only a large part of the watershed of the Kankakee but also a part of the Tippecanoe watershed. It embraces an area of approximately 3,000 square miles, in which sand deposits are nearly continuous. To this about 300 square miles should be added to extend the area to the extreme limits of the sand ridges.

RANGE IN ALTITUDE OF THE BORDER OF THE SAND.

At the eastern border plane-surfaced deposits of sand and also of gravel occur up to an altitude of about 750 feet, and dunes are found on the moraine at an altitude of fully 800 feet above tide. Along the south border the altitude of the sand ridge ranges from 700 feet or less at the Tippecanoe River to about 750 feet in Cass County and in western White and northern Benton counties. The altitude decreases upon passing westward from Benton County, the highest sand deposits in western Iroquois County, Illinois, being about 675 feet, and the outlet from the Iroquois to the Vermilion across Ford County scarcely 650 feet. The highest well-defined beach along the Illinois in the Morris Basin is but 560 feet. On the north border of the Kankakee marsh the altitude decreases from 750 feet or more in western St. Joseph County, Indiana, to about 650 feet at the State line and 570 feet at the mouth of the river. In general there is a westward descent in the sand-covered area, the only prominent exception being a depression in the southeast part on the borders of the Tippecanoe River. The outer sand ridge there stands fully 50 feet lower than 20 miles west at the line of White and Benton counties. The outer ridge is maintained continuously up this grade of 50 feet, from Reynolds to the Benton

County line, and thence westward down a similar grade to where it dies out near Kentland (Purdue). The long ridge a few miles to the north apparently holds a nearly uniform elevation about 680 or 685 feet above tide. As indicated in the topographic map, Pl. III, much of the area east of the State line stands above 700 feet. It should also be noted that in the midst of the sandy area the altitude is about as great as on the borders.

SURFACE CONTOURS.

The greater part of the sand-covered area has a nearly plane surface. The Kankakee marsh, with an area of nearly 1,000 square miles, is very flat, while the portion north of the marsh has scarcely any ridges worthy of note. In southeastern Pulaski and northern White counties, Indiana, the surface is mainly level and level tracts are quite extensive in southern Jasper County. In Illinois the surface is mainly plane, except on the outer face of the Iroquois moraine and in a belt a few miles wide which follows the south border of the Kankakee River, in both of which places there are ridges and dunes of some prominence.

The ridged portions of the sand in Indiana occupy southeastern Stark, much of Pulaski, and the central portions of Jasper and Newton counties, all of which lie southeast of the Kankakee marsh, as well as a narrow strip on the east and south borders of the sand area in Fulton, Cass, White, and Jasper counties. There are also scattering ridges in the midst of the level portions of the sand area in that State.

The most prominent ridges are 35 or 40 feet in height, but the majority are less than 20 feet, and many are only 5 or 10 feet. The individual ridges vary in breadth from 50 feet or less up to nearly one-eighth mile, but are usually about 200 to 300 feet. Among the ridges, even where most prominent, there are narrow strips with nearly plane surface.

The prevailing trend of the ridges is usually easy to determine, though in places the ridges wind about and interlock, forming an intricate network. Those on the east border, in Pulaski County, Indiana, show a tendency to a north-to-south trend, while those on the south border in Cass, White, and Jasper counties, trend nearly east to west. Those on the south border of the Kankakee trend about with the course of the stream, south of west in the Indiana portion and north of west in the Illinois portion. Between the ridges bordering the Kankakee in Indiana, and those on the south and east

borders of the sand area, the trend is not so easily systematized. The ridges there are arranged in groups or strips, among which there are extensive plane tracts, often bowlder strewn, and having only a thin sand coating. Some attempts to systematize these ridges and associated bowldery tracts have been made both by Professor Chamberlin and Professor Purdue, but without the satisfactory results which they had sought to obtain.[1]

THICKNESS OF THE SAND.

The thickness of the sand varies, both because of aggregation in ridges and because of irregularities of the surface over which it is spread. In much of the region within the Tippecanoe drainage basin the sand is very thin except in the ridges. This condition prevails also over southern Jasper and Newton counties, Indiana, and in parts of Kankakee and Will counties, Illinois. An extensive region on either side of the Kankakee from eastern Iroquois and Kankakee counties, Illinois, eastward to Marshall and St. Joseph counties, Indiana, is covered with sand to a depth of several feet below the level of the base of the ridges. Throughout much of this region wells are obtained without passing below the sand. Their depth is shallow, being generally 10 feet or less on the flat tracts, and correspondingly deeper on ridges.

Averaging the available data the sand apparently amounts to a continuous sheet not far from 10 feet in depth, over the 3,000 square miles which it covers, or to 5.68 cubic miles.

VARIATIONS IN COARSENESS.

The sand presents but little variation in coarseness. It is usually sufficiently coarse for individual grains to be readily discerned by the naked eye and is seldom too coarse for plasterers' use. Coarse gravelly material is found in a ridge near Rensselaer and in beaches on the border of the Illinois in Grundy County, Illinois. There are also gravel plains on the border of the Valparaiso and Maxinkuckee moraines in Laporte and St. Joseph counties. With these exceptions it is rare to find in these deposits a pebble as coarse as a buckshot.

In the Iroquois Basin in Newton County, Indiana, and also in parts of Iroquois County, Illinois, thin beds of silt about as fine as loess and much

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[1] Professor Purdue contemplates further study of the region to determine whether it is possible to bring order out of the present apparent lack of system.

resembling it in appearance are present within the limits of the sandy ridges. These deposits are somewhat calcareous and in places carry small nodules of lime. The sand appears to graduate horizontally into the loess-like silt in passing westward down the Iroquois Valley from Jasper County into Newton County, Indiana, also in passing westward from the moraine in eastern Iroquois County, Illinois, into the lower districts along the Iroquois Valley. In a few places loess-like silt was found among the sand ridges on the immediate border of the moraine. With these exceptions there is but little silt or clayey material present. The flat areas are often sandy, and heavy beds of peat or surface muck are rare. In one locality near Reynolds, Indiana, beds of peaty muck containing vegetal remains are reported to underlie the sand ridges, thus denoting an interval of emergence or exposure to atmospheric action between the withdrawal of the ice sheet and the spreading out of the sand deposits. Well authenticated instances were found only along the south border of the sand area, and their significance is not understood.

INTERPRETATIONS.

The limits of the sand area on the north, east, and southeast being found in moraines, the question naturally arises whether the sand is not an outwash from one or more of the ice lobes which formed these bordering moraines. Furthermore, the direction of the retreat of the margin being such as to gradually uncover this area from its western toward its eastern and northern borders, it needs to be determined whether the sand-covered area may not have been gradually extended from the southwest toward the northeast.

Upon examining into the connection between the sand deposits and the moraines it is found that in the northeast part of the area the moraines have a gravelly outwash, but this does not oppose the view just suggested, since the gravel seems to graduate into sand upon passing from the moraines into the sand-covered area. There is also a change to sand along the immediate borders of the moraine, either upon passing south along the Maxinkuckee moraine, or west along the Valparaiso moraine.

Examining into the second question, it is found that the sand ridges in places alternate with bowlder belts in such manner as to lend some support to the view that the sand was deposited in connection with the northeast-

ward retreat of the ice margin. The bowlder belts may mark the successive ice margins. In this case the ridging of the sand may be due entirely to wind action, or the ridges may be esker-like accumulations formed beneath a nearly stagnant ice sheet. Perhaps a systematic relation between the bowlder belts and the sandy areas may yet be worked out. At present the courses of the bowlder belts seem less systematic than would be expected under this hypothesis, so that this matter is still in question. The presence of beds of peat and muck at the base of the sand, which is a conspicuous feature in the vicinity of Reynolds, Indiana, perhaps opposes this interpretation, since it calls for an interval of emergence with exposure to atmospheric action between the withdrawal of the ice sheet and the deposition of the sand. The development of the peaty muck may, however, not prove fatal to this interpretation, since it is apparently limited in extent and demands no great length of time. The outwash, where most vigorous, may have caused the sand to encroach upon peat bogs in the outlying districts. In some cases it is probable that wind may have drifted the sand in such manner as to bury the peat bogs. That wind action has been influential in heaping up the sand throughout this area can scarcely be questioned.

An alternative interpretation to that of a gradually formed glacial outwash at the margins of receding ice lobes is found in the hypothesis that this sand-covered region is the bottom of an extensive lake in which the waves washed the till sheet and formed the sand. This hypothesis need not require that the entire sandy area was at any one time covered by a lake. It may also admit the application of the hypothesis of glacial outwash in explanation of the gravel and sand on the east and north borders, where the altitude is greater than on the south and west borders of the sand-covered area. It would differ from the former hypothesis in requiring a larger amount of static water and greater influence of waves. Were the upper or southern ridge of sand on the south border of the sand-covered region horizontal or even slightly tilted toward the east, it would give support to this hypothesis, for the ridge certainly bears a strong resemblance to a lake beach, but the fluctuations in level (from 675 to 750 feet above tide) seem too great to be accounted for by the warping of an originally horizontal line, and especially since the departure from the horizontal is in the form of wave-like oscillations instead of a regular uplift. Furthermore, the nearly parallel ridge a few miles to the north does not show similar warping. The supposed

extensive lake, therefore, can scarcely have had a level on its south border higher than the lower parts of the ridge that forms that border of the sandy area, or 675 to 685 feet above tide. This is about the elevation of the sandy ridge which leads from Monon Creek west to Percy Junction. It is also about the elevation of the eastern end of the Kankakee marsh at its junction with the gravel plains bordering the Valparaiso and Maxinkuckee moraines. It is fully 50 feet lower than the highest parts of the sand-covered area, not only those on the east borders but also points in the interior. A lake with this elevation could have had but shallow depth throughout much of the Indiana portion, and interrupted as it must have been by numerous islands it could scarcely have allowed wave action of much strength. It, therefore, seems improbable that lake waves should have caused the formation and deposition of much of the sand.

The hypothesis of glacial outwash as the chief contributor of sand, and of wind as an important distributor, apparently needs to be supplemented by that of the presence of a shallow body of water over much of the sandy area during and for some time subsequent to the retreat of the ice lobes. Even now much of the Kankakee marsh is covered throughout the greater part of the year by a broad shallow body of water in which the current is very sluggish and which resembles a lake more than a stream.

The western portion of this sandy area needs separate interpretation, since the sand deposits there appear to have had a history somewhat independent of the eastern portion.

As above noted, the sand deposits on the outer or western face of the Iroquois moraine in eastern Iroquois County in all probability were largely contributed by the ice sheet at the time that moraine was forming. This being the case, they antedate the deposits found east of that moraine. In case the correlation of the Iroquois moraine with the bowldery strip along the south side of the Kankakee in Will and Kankakee counties, Illinois, is sustained, the sandy belts found in close association with these bowlders would perhaps be of the same age as those of northeastern Iroquois County, Illinois, with which they connect in southeastern Kankakee County. It seems probable that a shallow lake occupied northern Iroquois County at that time. Possibly it stood as high as the sand ridge which leads through Onarga and Ridgeville (675 feet above tide), though it seems more probable that it had shrunk to a lower level, since there appears to have

been at that time no obstacle to a discharge through the Kankakee Basin to the Illinois.

The basin at the head of the Illinois apparently held a lake for a longer period than the remainder of the region under discussion. In all probability a ponding of waters in front of the retreating ice sheet occurred immediately upon the withdrawal of the ice sheet from the Marseilles moraine. At first the waters may have found escape through the gaps in the moraine above noted, which stand at about the level of the inner border of the moraine, at an altitude 640 or 650 feet above tide. The gap along the line of the present Illinois River seems to have eventually drawn away the drainage from the other gaps. Evidence that lake water stood high enough to discharge through these gaps is found in deposits of sand which coat the till for some distance back from each of them, and in silt deposits spread more widely over the basin; also in a greater smoothness of surface below the level of these gaps than above that level.

The outlet across the Marseilles moraine and districts to the west along the line of the Illinois River was probably cut down very slowly, since much rock has been excavated by it. Even as late as the time the Valparaiso moraine was formed the outlet had not been cut down sufficiently to drain the lake in the basin at the head of the Illinois. As already noted, terraces on the Des Plaines River, heading in the Valparaiso moraine, which were formed in connection with the moraine, indicate that a lake stood in this basin at the head of the Illinois while they were forming. These terraces and also beaches in the Morris Basin indicate that its level was about 560 feet above tide, or 60 feet above the present head of the Illinois River.

This stage of the lake in the Morris Basin having been thus connected with the Valparaiso moraine, it is evident that the level was equally high in the earlier stage, when the outwash of sand occurred on the lower Iroquois and lower Kankakee. The lake level extended up the Kankakee Valley about as far as Braidwood, where the sand dunes set in. It seems not improbable that drainage conditions were such as to produce only a sluggish flow of water in the lower Kankakee at that time, similar to the present sluggish current of the upper portion of that stream. In this connection it may be remarked that it is doubtful if any appreciable excavation of the Kankakee Valley below Momence had occurred up to the time of the formation of the Valparaiso moraine. It was subsequent to this that

the Illinois became an outlet for the large amount of water discharged from Lake Chicago, and which caused a rapid deepening of the outlet and greatly hastened the draining of the lake in the Morris Basin. During a portion of the time that the Chicago outlet was in operation the Kankakee afforded a line of discharge for the St. Joseph River and the waters poured into it from the melting Saginaw lobe, which probably accounts for much of the erosion accomplished along the borders of that stream and a measurable part of that along the Illinois. This deepening of channel at the mouth of the Kankakee has led to an excavation on the lower portion of the Kankakee, which has progressed no farther up the valley than the rock barrier at Momence. The upper portion is still flowing at the low gradient of its large predecessor.

Reviewing the above observations, the interpretation which seems to best apply to this region admits only lakes of small extent or shallow depth, and opposes the occupancy of the entire sandy area by water at any one time. Glacial lakes held in the Morris Basin and the Iroquois Basin may, at their maximum extent, have formed a single body of water with an outlet or outlets about 650 feet above tide. This lake level had probably become lowered somewhat before the sand deposits were made in northeastern Iroquois County and along the lower course of the Kankakee, and possibly may have been cut down nearly to the level of the uppermost well-defined beach in the Morris Basin (560 feet). The sand deposits in the upper Kankakee region and neighboring districts on the south seem best explained as glacial outwash made during the withdrawal of the ice sheet to the position marked by the Valparaiso and Maxinkuckee moraines, and probably continued during the formation of those moraines. The upper Kankakee Basin seems then to have been occupied only by a shallow body of water which may have extended but little beyond the limits of the Kankakee marsh. The method of formation of the well-defined south border of the sand area in western Indiana, with its fluctuations in elevation, is as yet not understood. The distribution of the sand ridges and their alternation with bowldery belts, both in the Indiana district and along the south border of the Kankakee, are features which do not lend themselves to a ready solution. Indeed, the entire interpretation is less definite than could be desired.

SECTION IV. THE VALPARAISO MORAINIC SYSTEM.

The morainic system discussed under this name was brought to notice by Chamberlin in an early report of this Survey, under the title "The Moraine of the Lake Michigan Glacier."[1] Inasmuch as the morainic system was formed by an ice lobe which was almost confined to the basin of Lake Michigan, it seems convenient to speak of it as the product of the Lake Michigan glacier rather than to apply the more comprehensive term, Illinois Glacial Lobe; and the drift is conveniently referred to as the Lake Michigan drift.

The course of this morainic system as outlined in the Third Annual Report was chiefly traced from northeastern Illinois around the head of Lake Michigan by Prof. L. C. Wooster, who subsequently examined it in more detail. Chamberlin gave it considerable study in connection with his investigations farther north and east. The writer's studies began after the publication of that report. He has given this morainic system but little attention in northwestern Indiana, but has made a somewhat detailed study of it in southwestern Michigan and in portions of northeastern Illinois not covered by Wooster.

The name Valparaiso, taken from a city of that name located on a very prominent portion of the morainic system in northwestern Indiana, was suggested by Wooster in a manuscript report and has been used by the writer in previous papers which touch upon this system.

DISTRIBUTION.

As pointed out by Chamberlin, this morainic system "may be likened to an immense U, embracing the great lake between its arms." It has a length from north to south of over 100 miles, if portions coalesced with older moraines on its outer border be included. The breadth of the lobe averages nearly 100 miles. The parallelism of the morainic system to the shore of Lake Michigan is one of its most striking features. In the portion examined by the writer, which lies south of the latitude of the Illinois and Wisconsin State line, the inner border is usually less than 15 miles and at its closest approach is only about 6 miles distant from the lake, and this close parallelism is known to be continued still farther north. In this portion the breadth of the morainic system ranges from 5 or 6 miles up to nearly

[1] Third Annual Report U. S. Geol. Survey, 1881–82, pp. 322–325.

20 miles. It is narrowest just south of the Michigan and Indiana State line and broadest in the vicinity of the Indiana and Illinois State line. The glacial map (Pl. VI) sets forth its variations in width.

In northern Illinois this morainic system becomes merged with older moraines in the composite belt already discussed, but it evidently finds its continuation northward along the inner or eastern border of that belt as far as the peninsula between Green Bay and Lake Michigan.

The Valparaiso morainic system in Michigan is made to include the entire bulky morainic belt of Lake Michigan drift, from the Grand River Valley southward, though it consists in places of two or more constituent ridges. These ridges coalesce and separate by turns, but nowhere become so distinctly separated as to appear to merit individual names and separate descriptions. This belt of Lake Michigan drift is distinct from moraines of the Saginaw lobe in Berrien and southern Van Buren counties, but in northern Van Buren County it becomes so closely associated with the Saginaw moraines that the line of separation can be made out only upon close study. The moraines remain closely associated from Van Buren County northward at least as far as Grand Rapids, beyond which the writer has not carried his investigations. Investigations by the Michigan survey indicate that later moraines may conceal it in the northern part of the Southern Peninsula.

BORDER BETWEEN THE LAKE MICHIGAN AND SAGINAW BAY LOBES.

The nature of the border line between this morainic system and the neighboring morainic system of the Saginaw lobe merits special attention. The description begins in southern Allegan County and is carried southward to northern Indiana.

The eastern border of the Valparaiso system, as shown in Pl. XV, is apparently found in the eastern tier of townships in Allegan County from the northeast corner of the county southward to the vicinity of Monteith. The moraine here has an overwash gravel plain along its eastern border occupying the western half of Martin and central part of Wayland townships. This plain shows a perceptible eastward slope away from the moraine. Along its east border there is a moraine of the Saginaw lobe. This moraine swings westward just south of Monteith and the two ice lobes appear to have come into close contact for a few miles south from that point. The Saginaw movement was sufficiently strong, not only to meet the ice lobe on

PLEISTOCENE MAP OF SOUTHWESTERN MICHIGAN

BY FRANK LEVERETT

1898.

the west, but to extend the border between the lobes several miles to the west. This border assumes a nearly east to west course, across Otsego and Trowbridge townships. In the latter township it has the form of a double ridge with only the Kalamazoo River between the two members. A till plain fits closely about the border of the north member on the west and north, which rises toward the morainic ridge, apparently indicating that the Lake Michigan movement extended to this ridge. Similarly the south member is bordered by a plain on the south and east, which rises toward the ridge and indicates that it was formed by the Saginaw movement.

The Saginaw movement apparently extended only to the western part of Trowbridge Township, for the ridge on the south side of the Kalamazoo River swings around on the west and south border of the till plain just referred to. The double ridge, which in Otsego and Trowbridge townships trends toward the west, here becomes combined into a single belt and swings around through Cheshire Township to a southerly course. It presents sloping till plains on each side rising toward it. As the combined morainic belt enters Van Buren County it again becomes separated. The Saginaw moraine turns to the east, crossing the northern part of Pine Grove Township, while the moraine of the Lake Michigan lobe bears nearly due south through the eastern part of Bloomingdale Township. An overwash gravel plain common to the two lobes, covering 5 or 6 square miles, separates the two moraines in western Pine Grove Township, while each moraine has a till plain fitting about its opposite border. In each case the till plain rises toward the moraine which it borders.

In the townships south of Bloomingdale and Pine Grove (Waverly and Almena) both moraines are obscure near their line of junction, there being instead an extensive swamp, which borders Pawpaw River and is known as the Pawpaw Swamp, in which only occasional clusters of knolls appear. The Lake Michigan movement apparently extended about to the border between Waverly and Almena townships, for the till plain, which farther north lies west of the eastern or outer member of the Lake Michigan movement, extends about to this line and borders the swamp just mentioned on the west. The Saginaw movement, which produced a bulky moraine in Pine Grove Township, has scarcely any morainic features in the township on the south. The till plain, which in Pine Grove Township lies east of the prominent morainic ridge, continues southward along the east border of the Pawpaw Swamp.

Immediately west of the village of Pawpaw, at the south border of the Pawpaw Swamp, the Lake Michigan moraine again becomes prominent. South of this latitude the Saginaw and Lake Michigan movements apparently lacked a few miles of meeting, and the interval is filled with a great gravel deposit through which the Dowagiac River has its course. The gravel plain descends toward the river from either border. It is therefore a double outwash, that on the west being the outwash from the Lake Michigan lobe and that on the east from the Saginaw Bay lobe. The gravel plain formed as an outwash from the Lake Michigan lobe is characterized by numerous lakelets, many of which are without surface outlet. The basins which they occupy are so deep that the water surface of the lakes is in some cases 40 or 50 feet below the general level of the gravel plain on their borders.

Immediately west of Niles is a prominent morainic ridge which extends southwestward into Indiana and there turns south and dies away in the plain at the head of the Kankakee River. It is slightly outside the regular border of the Valparaiso moraine and is separated from it by a narrow valley-like depression occupied for a few miles, between Niles and Buchanan, by the southwest flowing portion of the St. Joseph River. This moraine belongs perhaps to the Saginaw series, for its trend harmonizes more closely with that of the Saginaw moraine east of it than with the Valparaiso moraine west of it. Furthermore, its surface bowlders apparently bear more resemblance to those found in the Saginaw moraines than those on the Valparaiso moraine. The moraine is accordingly discussed in connection with the Saginaw moraines in another report now in preparation. A morainic tract in the northwest township of Cass County is also discussed in that report as a possible Saginaw moraine.

From the State line of Michigan and Indiana the Valparaiso moraine bears southwestward and the neighboring Saginaw moraine (the Maxinkuckee) bears southward while the broad Kankakee marsh with its bordering gravel plains occupies the interval between them.

Thus it appears that the two ice lobes in places had margins so widely separated that each produced a gravel apron of its own on its outer margin; in other places a single overwash apron was produced, as in Pine Grove Township, Van Buren County, and Martin Township, Allegan County; in other places the two glaciers formed moraines side by side, with no overwash apron between, as in Trowbridge Township, where the Kalamazoo River flows between them; in Cheshire Township a single moraine was

produced by the two, and we find north of Pawpaw, the last extreme, a place where neither glacier produced a definite ridge at the point where the two lobes came in contact.

RANGE IN ALTITUDE.

The inner border of the Valparaiso morainic system, so far as examined, presents but little range in altitude, being usually between 650 and 690 feet above tide, or 70 to 110 feet above the level of Lake Michigan. From the inner border there is usually a rise of at least 100 feet, and in places of 200 feet or more, to the main crest of the morainic system. This crest in the Illinois portion ranges from about 750 feet up to nearly 900 feet above tide, being highest in the vicinity of Lake Zurich, in southern Lake County, and lowest on the borders of the Des Plaines River, in Will County. In the Indiana portion the crest ranges from about 750 feet in Lake County to nearly 900 feet in Laporte County. In the Michigan portion the crest is 750 to 800 feet in the vicinity of the St. Joseph River and northward nearly to the line of Allegan and Van Buren counties. But in Allegan County it presents more range, the highest points being fully 900 feet, while the low points near the Kalamazoo River rise but little above 700 feet.

On the outer border of the morainic system the altitude is generally much higher than on the inner border, though in Kankakee and southern Will counties, Illinois, the difference in the elevation of the inner and outer borders is only a few feet. The difference is also slight in Lake and western Porter counties, Indiana. In the vicinity of the Wisconsin line and southward as far as Elgin, Illinois, the outer border stands between 750 and 775 feet. It declines to about 700 feet at Naperville, Illinois, and to about 650 feet in southwestern Will County, Illinois It rises thence gradually eastward up the Kankakee Valley, reaching 700 feet in eastern Porter County, Indiana. There is then a more rapid rise and an altitude of about 800 feet is attained in the vicinity of Laporte, Indiana. This altitude is maintained eastward from Laporte to the border of St. Joseph County, Indiana. A descent there begins toward the St. Joseph River and the altitude decreases to about 710 feet on the borders of that stream north of Niles, Michigan. In passing northward, up the Dowagiac Valley, the altitude along the outer border of this morainic system increases to about 800 feet in Keeler and Hamilton townships, Van Buren County, Michigan. It declines again to about 700 feet at the Pawpaw marsh in

Almena Township, but rises to 800 feet at the gravel plain in western Pine Grove Township. At the Kalamazoo River it is only about 700 feet, but on the gravel plain in Martin and Wayland townships, Allegan County, its altitude is 800 to 850 feet. The following table of elevations taken from the railway profiles which cross this morainic system, is designed to set forth the altitude of the inner border, the main crest, and the outer border. Numerals inclosed in parentheses represent the general elevation of the crest in the vicinity of the railway line in places where the railway either makes a deep cut or passes the crest along a drainage line.

Table of elevations on Valparaiso moraine.

Railroad.	Inner border.	Crest.	Outer border.
	Feet.	*Feet.*	*Feet.*
Elgin, Joliet and Eastern, in Lake County, Ill	720	880	770
Wisconsin Central	683	823	778
Chicago, Milwaukee and St. Paul	646	812	768
Chicago and Northwestern (Wisconsin Division)	650	867	772
Chicago and Northwestern (Omaha Division)	641	760 (790)	750
Chicago, Burlington and Quincy	646	763	700
Wabash	665	712 (750)	a 680
Chicago, Rock Island and Pacific	630	725 (750)	a 680
Illinois Central	650	806	a 710
Chicago and Eastern Illinois	632	777	a 713
Louisville, New Albany and Chicago (Chicago Division)	640	740±	660
Pan Handle	650	740±	673
Chicago and Erie	650	760±	685
Pittsburg, Fort Wayne and Chicago	660	775±	730
Chicago and Grand Trunk	650	825	770
Baltimore and Ohio	670	(850)	775
Lake Shore and Michigan Southern	675	851	800
Lake Erie and Western	685	863	790
Chicago and Western Michigan	690	863	775
Vandalia Line	680	(750)	730
Michigan Central	680	(750)	730
Chicago and Western Michigan	670	785	710
Kalamazoo and South Haven Division of Michigan Central	680	825	800

a Outer border of main ridge.

SURFACE CONTOURS.

The Valparaiso morainic system is nearly as complex as the Bloomington and Champaign systems, but it does not admit of separation into such distinct ridges. Around the southwestern end of the loop in Dupage and Will counties, Illinois, it is possible to trace three distinct crest lines. Usually, however, there are but two, and in places but a single crest. Where most clearly separable into distinct ridges, there is one ridge which much exceeds the others in bulk, and constitutes the main ridge of the system. Where not clearly separable, the minor ridges either become coalesced with the main ridge or present imperfect ridging.

In the vicinity of the Wisconsin and Illinois line and thence southward through Lake County, Illinois, the main ridge occupies the eastern part of the system. In the western part the ridging is less definite, though the morainic expression is in places more pronounced than in the eastern part. Upon passing southward across northwestern Cook County a minor ridge makes its appearance on the eastern slope, and is separated from the main ridge by the valley of Salt Creek. This ridge continues across Dupage County. The main ridge covers nearly the entire width of the system in northwestern Cook County, but in Dupage County there is not only the minor ridge on the eastern or inner border, but also one on the western or outer border of the system. The valley of East Dupage River separates the main ridge from the minor ridge west of it.

From the vicinity of the Des Plaines River eastward to the border of Indiana the three ridges just mentioned are distinctly traceable, the main ridge occupying the central part of the system and the minor ridges the outer and inner borders. The ridge on the outer border is in places separated from the main ridge by a narrow plain, but is closely associated with it near the State line and also from the Des Plaines River northward. The interval between the main ridge and the minor ridge on the inner border is narrow and generally nearly as undulating as the ridges. Near Matteson, however, a small plane tract separates the two ridges.

In Lake County, Indiana, the ridge on the north or inner border of the morainic system becomes nearly as prominent as the main ridge, and constitutes the water parting between the Kankakee River system and Lake Michigan. It also constitutes the water parting in a few places west of the State line.

Upon passing eastward from Lake County, Indiana, the several ridges become combined into a single great ridge which admits of but little separation into distinct members in Porter and Laporte counties, Indiana, and in southern Berrien County, Michigan. In northeastern Berrien County two distinct ridges are developed, between which Pipestone Creek flows in a southwestward course. Farther north the morainic system consists usually of a main ridge on the eastern or outer border and ridges of more or less definiteness near the western border, between which there are lower tracts with gently undulating surface.

The ridges just discussed, although bulky, are in places less impressive topographic features than the knolls and basins which dot their surfaces. They usually rise gradually from border to crest, and their dimensions can be appreciated only by measurements with surveyor's level or other instruments. The inner border in Porter and Laporte counties, however, usually shows an abrupt rise of 100 feet or more and portions of the inner border in Michigan are also abrupt. Such is the case in the vicinity of the St. Joseph River in central Berrien County, and at frequent intervals from that river northward to the Kalamazoo River.

Considerable variation in surface contour is displayed in each of the States which this morainic system traverses. In the Illinois portion the surface is usually gently undulating, with knolls 15 to 30 feet in height, separated by winding sags and shallow basins. The trend of these knolls, when on the crest and outer part of the morainic system, is usually about in line with the trend of the ridges whose surface they occupy. Near the inner border of the moraine, however, the knolls frequently show a tendency to elongation at right angles with the trend of the morainic system. The crest of the main ridge often rises abruptly 30 or 40 feet above the remainder of the moraine in a narrow ridge or chain of knolls. In Lake County, Illinois, there are numerous small lakes occupying the basins among the morainic knolls. These range in size from a few acres up to several square miles. They are usually shallow, a depth of 50 feet being seldom attained, while the majority are but 10 or 15 feet. Among the lakes there are knolls and irregular ridges rising 10 to 50 feet above the surface. Some of the lakes are bordered by extensive marshes on one or more sides, which were formerly probably covered by the lakes, for it is not rare to find beaches a few feet above the present level of a lake. This morainic

system, as indicated below, is deeply trenched by the outlet from the glacial Lake Chicago, which discharged from the southern end of the Lake Michigan Basin through the Des Plaines Valley.

In Lake County, Indiana, the contours are generally subdued, there being few knolls more than 20 or 30 feet in height. Tributaries of the Kankakee lead southward from the belt on the north border, greatly interrupting the continuity of the main ridge. Similarly in Will County, Illinois, the main ridge is trenched by the headwater tributaries of Hickory Creek and of other streams flowing southward to the Des Plaines or Kankakee.

In Porter and Laporte counties, Indiana, the moraine is characterized by sharper knolls than in Lake County and, as noted above, rises with great prominence on its inner border. Lakelets are inclosed among the knolls and occur also on the outer border of the morainic system in basins occupying the edge of the overwash gravel apron.

From the line of Indiana and Michigan northward the morainic system usually presents sharp contours. The knolls range in height from 15 or 20 feet up to 60 or 80 feet. There are several places in which elevated tracts several square miles in extent rise above the general level of neighboring portions of the moraine. The most notable instances are as follows: In Bainbridge Township, Berrien County; in central Lawrence Township, Van Buren County; in southern Arlington Township, Van Buren County; in northern Bloomingdale Township, Van Buren County; in northwestern Trowbridge and northern Cheshire townships, Allegan County, and in a tract north of Allegan. There is usually an abrupt border on two or more sides of these tracts, with a relief of 60 to 100 feet above neighboring portions of the moraine. In the elevated tract north of Allegan the descent is abrupt both on the north and east sides, and in Cheshire Township on the north and west sides. The morainic tracts in northern Bloomingdale and southern Cheshire have no very abrupt borders. The tract in Arlington Township, with arm-like projections into Hartford Township, has an abrupt border on all sides. The tract in Bainbridge Township has an abrupt border on the north and west and also on portions of the east and south. Were it not for the relief, these tracts would differ but little from the neighboring lower portions of the morainic system, for they usually present only small knolls and ridges on their surfaces.

A few small tracts of elevated land occur along the west border of the morainic system in southwestern Michigan. Such tracts in Geneva, Bangor, and Watervliet townships, Van Buren County, have extreme elevations of 50 to 75 feet above the bordering plains. The swells rise one above another in passing from the plains to the highest portions of these tracts and the border is less abrupt than in the larger tracts above mentioned.

There are a few points where very sharp knobs were noted which rise 60 or 80 feet above the border portions of the moraine. These occur in Watson Township, Allegan County; in the vicinity of Great Bear Lake in Van Buren County; on the south side of Pawpaw River, near Lawrence, and in several places along the eastern border of the morainic system in Van Buren and Berrien counties.

In the Michigan portion of this morainic system marshes are a very common feature, there being usually several inclosed among the morainic knolls in each township. Lakes are also a common feature from northern Berrien County northward. They are in some cases two or three square miles in area, but usually occupy less than a square mile. So far as known they are shallow and, like those of the Illinois portion, are bordered by marshes which seem to have been formerly covered by lake water. There are also lakes along the eastern border of the morainic system indenting the gravel plain. These are conspicuous in northwestern Cass and southern Van Buren counties.

DETAILED DESCRIPTION OF THE MICHIGAN PORTION.

The Michigan portion of this morainic system was examined in more detail than the remainder of the system because its surface contours are more variable and because it had received very little attention from the earlier students. It seems appropriate, therefore, to present the following detailed discussion of the topography of this portion. The area first considered lies in central Allegan County, and the discussion is then extended to points farther south.

In T. 2 N. the moraine consists of two well-defined ridges separated by a till plain. A line passing across the morainic system from west to east shows the following features: West of the western ridge is a broad plain covered with sand called the "Pine Plain." This plain stands 50 to 75 feet above Lake Michigan. In passing eastward from it an abrupt rise is made

into a belt of billowy land standing 200 to 260 feet above the lake, the most elevated portion being at the east in central Allegan Township. Here a sudden descent is made to a narrow till plain standing 150 to 160 feet above Lake Michigan, east of which an abrupt rise takes place in Watson Township to an elevation of 260 to 330 feet above the lake, or 840 to 910 feet above tide. This rolling belt continues to the west part of Martin Township, where a gravel apron borders the moraine, having an elevation of 240 to 260 feet above Lake Michigan, or 820 to 840 feet above tide. The very elevated portion of the moraine in Watson Township appears to be doubled upon itself in a peculiar manner. Its western part is bordered on the north, west, and south by a till plain, and this western end forms a very prominent part of the moraine, having knobs 80 feet or more in height above the bordering basins and plains.

Passing now to T. 1 N., it is found that the eastern portion of the moraine in Watson Township continues to the south part of that township and there turns abruptly to the west, following the north side of the Kalamazoo River from Otsego to Allegan, along the south border of the till plain referred to above. At Allegan it joins a rolling sandy tract which lies west of that city, and the combined belt takes a southwesterly course, occupying nearly the whole of Cheshire Township. The north and west tiers of sections are partly on the moraine and partly on the sandy plain which borders it on the west. The morainic system is here narrowed to the width of a single township and has the Saginaw moraines combined with its eastern border and the Pine Plains bordering it on the west.

Passing to T. 1 S., the morainic belt is found to spread out to a width of nearly 15 miles. Its inner border takes a nearly west course to the vicinity of Grand Junction. It then passes south to Breedsville, lying a short distance east of the Chicago and West Michigan Railroad. West from this railroad in Geneva Township are isolated tracts with undulatory surfaces surrounded by marshes, swamps, and till plains. These knolly tracts extend in two instances north across the base line into Allegan County, so that the whole district south of the "Pine Plains" in both T. 1 N. and T. 1 S. and east of a till ridge (Covert Ridge) which borders Lake Michigan in South Haven and Casco townships, is in places more or less morainic in topography, but the main morainic belt lies east of the Chicago and Western Michigan Railroad.

Passing eastward over this belt there is an ascent, gradual at first, over a sandy tract in Columbia Township, then over an undulatory till ridge in Bloomingdale Township, which changes to a plain in the central part of the township; then in the eastern part of this township a rapid ascent is made to the high portion of the moraine which forms the eastern border of the Lake Michigan drift. This border is at Gobles, on the line of the Kalamazoo and South Haven Division of the Michigan Central Railroad, and lies near the line between Bloomingdale and Pine Grove townships throughout their whole length. The following elevations of stations along the railroad give a fair idea of the rise of the moraine toward the east from Grand Junction to Gobles:

Elevations of stations along the Kalamazoo and South Haven Division of the Michigan Central Railroad.

	Feet above tide.
Grand Junction	678
Columbia	682
Berlamont	700
Bloomingdale	731
Gobles	803

At least 60 feet of the rise between Bloomingdale and Gobles is made within 1½ miles of the latter town. There is scarcely any descent to the border of the overwash plain or apron east of Gobles, but this plain descends 20 feet or more in a mile toward the east to the border of the Saginaw moraine near Pine Grove Mills. This may not be true except along the railroad, but since this passes through a wide part of the overwash plain the fact is significant.

In T. 2 S. the morainic ridge which is so prominent at Gobles grows feebler for 3 miles or more along the line between Almena and Waverly townships, as it approaches Pawpaw River, rising scarcely 50 feet above this stream and still less above Brandywine Creek, which lies along its western border. The undulations are less sharp than in T. 1 S. On the south side of Pawpaw River the outer border of the moraine takes a nearly east to west course for 5 or 6 miles. Its prominent portion lies mainly in T. 3 S., barely reaching into Waverly Township. There is a gap 2 or 3 miles long just north of the village of Pawpaw where no moraine is developed, but the swamps which follow Pawpaw River are bordered on the east by the overwash apron of a moraine of the Saginaw series. West of Pawpaw the moraine assumes a strength of development even greater than

that near Gobles, rising nearly 150 feet above the Pawpaw River swamps, 4 to 6 miles west of the village of Pawpaw, and having a breadth from the swamp on the north to an overwash apron on the south of only 1½ to 2 miles.

Waverly Township is much of it comparatively level and swampy, but the topography of the northwestern part is morainic. This belt connects on the north with the morainic belt which passes through western Bloomingdale and eastern Columbia townships.

In northeastern Arlington Township, which adjoins Waverly on the west, is a swamp, which comprises about one-third of the township. It is bordered on the north and east by the billowy belt in Columbia, Bloomington, and Waverly townships, and on the southeast by an elevated billowy tract in Arlington Township, which constitutes the most prominent portion of the moraine in this tier of townships. This prominent morainic belt extends southwest through southeastern Bangor Township to the Pawpaw River, near Hartford. Its south border lies along the river for a distance of nearly 10 miles from the east line of Arlington Township to the village of Hartford. The river is also bordered on the south by a similar prominent belt, which is described in connection with the next tier of townships.

Bangor Township, which lies west of Arlington, has a series of swamps, till plains, and island-like billowy tracts, the swamps and till plains together occupying more than half of the surface.

The moraine in this tier of townships, therefore, has a width of about 18 miles, and is highest in the middle portion, while in the tier of townships on the north it is nearly as wide, but its most prominent part is the eastern border. The curve in the outer border of the moraine makes the prominent morainic belt south of Waverly Township the correlative of the morainic belt near Gobles, in T. 1 S., and this belt is more prominent than the middle portion in Arlington Township. The rule, therefore, still holds good—if we overlook the break north of Pawpaw—that the eastern or outer border is the highest part of the moraine, and this rule continues to apply as far south as the Indiana line.

In T. 3 S., at the western border of the morainic belt in Watervliet Township, there is immediately east of the till ridge which cuts across its northwest corner a series of till plains interspersed with island-like billowy tracts and dotted with lakelets, differing from Bangor Township in having

lakelets instead of swamps. In Hartford Township, which borders Watervliet on the east, there are till plains, sand plains, and island-like billowy belts over about two-thirds of the township, but the two tiers of sections in the east contain an elevated part of the moraine. Lawrence Township, which lies east of Hartford, has a prominent part of the moraine occupying nearly the whole of its surface, there being but two notable exceptions, the valley of the Pawpaw River, which passes from east to west through the northern part of the township, and the overwash apron which borders the moraine in the east part of the township. The overwash apron swings around the moraine across Hamilton Township, which lies south of Lawrence, and thus in the north part of T. 4 S., as well as in T. 3 S., the morainic border has for several miles a nearly east to west trend. Continuing its course in T. 4 S., we find the morainic border turning southwest near Keeler Center and entering Cass County from the southwest corner of Keeler Township, cutting off a section or more of this county in its extreme northwest corner, then entering the eastern part of Pipestone Township, Berrien County.

Passing westward through T. 4 S., the moraine becomes prominent in western Keeler, Bainbridge, and eastern Benton townships. It divides in the southern part of Bainbridge township at Pipestone Lake, and from this point south, in Pipestone Township, incloses a low belt along the Pipestone River in which flowing wells have been obtained. The eastern limb passes southwest through the southeastern part of Pipestone Township, and the western limb passes southwest across the northwest corner of Pipestone Township into Sodus Township and occupies the eastern portion of this township to the St. Joseph River.

From Benton Township southward nearly to the Indiana line the western or inner border is more sharply defined than it is north of this township. It rises abruptly 100 feet or more above the swamps or till plains which lie along the foot of the range of sandy hills which form its front. For a few miles in southern Berrien County, Michigan, this border is not abrupt, but upon passing into Laporte County, Indiana, it again becomes abrupt and continues so across Laporte and Porter counties. Along the eastern or outer border in Berrien County lakes are numerous. They are usually in deep depressions 50 feet or more below bordering portions of the moraine. There are also lakes on the gravel plain outside the moraine, occupying basins

sunk 30 to 40 feet or more below the general level of the plain. The St. Joseph River is bordered by broad gravelly terraces 2 miles or more in width from the inner border of the moraine southward a short distance beyond Berrien Springs. From this point up to Buchanan the moraine borders the valley closely on each side. Above Buchanan the river is again bordered by gravel terraces which are cut in the gravel plain that was formed on the outer border of the moraine.

THICKNESS OF THE DRIFT.

Situated as the Valparaiso system is, in a district over which there have probably been several successive ice advances with intervening recessions, the drift can scarcely be supposed to belong solely to the advance which formed this morainic system. It is known that remnants of the sheets of the Illinoian and Iowan drift are present in northeastern Illinois and northwestern Indiana. There is also present a considerable amount of drift of the early Wisconsin series. The early Wisconsin drift is so similar to that of the Valparaiso drift sheet that it is doubtful if it can be readily distinguished or separated from it. There does not appear to be a well-defined soil horizon at the base of the Valparaiso sheet to mark the line of junction, such as occurs under wide areas at the base of the early Wisconsin drift. The thickness of the Valparaiso drift sheet can perhaps be best estimated by the relief, for it can scarcely be assumed to exceed greatly the measure of the outer-border relief of the moraine, except in places where there is a great gravel filling on that border. The gravel filling is of little consequence on the outer border of the Valparaiso morainic system in Illinois and in Lake and Porter counties, Indiana. Farther east and north it is of considerable depth. The relief in the Illinois portion is estimated to average about 65 feet. The average thickness of the Valparaiso sheet is probably somewhat less than the relief, since the sheet is markedly thinner on the borders of the morainic system than along its main crest.

In southwestern Michigan it is difficult to determine whether the early Wisconsin sheets are present in large amount. A fresh drift of great depth is found along the line of the morainic system and westward from it to the borders of Lake Michigan. In all probability the thickness of the Valparaiso sheet is as great in southwestern Michigan as in northeastern Illinois and northwestern Indiana, and it may be even greater.

The combined thickness of the several sheets of drift has been determined at various points along the line of this morainic system, while at other points wells have been sunk to great depth without reaching the bottom of the drift. The rock surface beneath the drift appears to be quite uneven, there being a known range from about 100 feet above the level of Lake Michigan to more than 100 feet below the surface of the lake. The following list of deep borings sets forth the variations in the thickness of the drift and the elevation of the rock surface:

List of borings showing thickness of drift along the Valparaiso morainic system.

	Thickness of drift.	Elevation of well mouth.	Elevation of rock surface.
	Feet.	*Feet.*	*Feet.*
At Ivanhoe, Illinois, on crest	290	800	510
Near Lake Zurich, on crest	*a* 267+	900	(?)
At Lake Zurich, 20 to 30 feet below crest	240+	880	(?)
Hainesville, near crest	287+	880	(?)
Gilmer, near crest	213+	820	(?)
Crest east of Wauconda	230+	850	(?)
Crest south of Barrington	315+	850	(?)
Barrington, 40 to 45 feet below crest	254	818	564
East of Elgin, near crest	220–240	850	610
Palatine and vicinity	100–170+	750	650
Near Schaumberg, along crest	190+	825	(?)
Arlington Heights, about 150 feet below crest	128	700	572
North of Arlington Heights, 20 to 30 feet above station	190	725	535
Near Spaulding, about 50 feet below crest	120	770	650
Bartlett, 10 to 20 feet below crest	100+	800	(?)
Ontarioville, near crest	140+	815	(?)
Roselle, about 50 feet below crest	100+	770	(?)
Crest south of Bloomingdale	162	800	638
Itasca	72+	692	(?)
Bensenville	97	677	580
Elmhurst	98	688	590
Turner Junction	116	765	649
Crest east of Naperville	115+	740	(?)
Downer's Grove	113+	720	(?)
Crest east of Downer's Grove	159	750	591
Near Clarendon Hills	160+	755	(?)
Crest northwest of Lemont	150	740	590
Crest of moraine east of Lockport	115+	725	(?)
Near Spencer	81	710	629

a Where the + sign is affixed the rock is not reached.

List of borings showing thickness of drift along the Valparaiso morainic system—Cont'd.

	Thickness of drift.	Elevation of well mouth.	Elevation of rock surface.
	Feet.	*Feet.*	*Feet.*
Crest near Frankfort	135+	780	(?)
Monee, on crest	180+	804	(?)
Crest near Goodenow	112+	780	(?)
Beecher	106+	720	(?)
Sec. 11, T. 34, R. XIV E	106+	720	(?)
Chicago Heights	30	690	660
Crown Point, Ind	176	736	560
Hebron, Ind	108	713	605
Three miles south of Wheeler, Ind	219+	700	(?)
Two miles north of Wheeler, Ind	200+	660	(?)
Valparaiso, Ind	125	715	590
Woodville, Ind	158+	687	(?)
Jackson Center, Ind	167+	825	(?)
Near Coburg, Ind	148+	800	(?)
Laporte, Ind	295	810	515
Berrien County, Mich., sec. 14, Bainbridge Township	117+	750	(?)
Berrien County, Mich., sec. 12, Bainbridge Township	125+	750	(?)
Berrien County, Mich., sec. 2, Pipestone Township	155+	700	(?)
Van Buren County, Mich., sec. 5, Hamilton Township	110+	800	(?)
Van Buren County, Mich., sec. 1, Lawrence Township	125+	800	(?)
Van Buren County, Mich., sec. 17, Lawrence Township	230+	775	(?)
Van Buren County, Mich., sec. 17, Bangor Township	104+	700	(?)
Van Buren County, Mich., sec. 11, Hartford Township	160+	730	(?)
Van Buren County, Mich., sec. 21, Arlington Township	125+	775	(?)
Van Buren County, Mich., sec. 23, Arlington Township	162+	775	(?)
Van Buren County, Mich., near Gobles	109+	800	(?)
Van Buren County, Mich., near Bloomingdale	110+	750	(?)
Van Buren County, Mich., near Columbia	178+	685	(?)
Van Buren County, Mich., sec. 25, Columbia Township	125+	750	(?)
Allegan County, Mich., Lee station	120+	648	(?)
Allegan County, Mich., sec. 19, Cheshire Township	108+	750	(?)
Allegan County, Mich., sec. 6, Martin Township	112+	820	(?)
Allegan County, Mich., sec. 20, Martin Township	150	820	670
Allegan County, Mich., sec. 9, Watson Township	150+	860	(?)
One mile south of Allegan	180+	710	(?)
Allegan waterworks	180+	650	(?)
East of Allegan	216+	710	(?)
Ohio Corners	95	750	655
Near Ohio Corners	165+	750	(?)

STRUCTURE OF THE DRIFT.

The drift of the Valparaiso sheet is found to show interesting changes in structure when followed around the head of Lake Michigan. In the Illinois portion it consists mainly of a soft blue till, similar to that forming the bulk of the moraines in the early Wisconsin series in that State. Upon passing eastward into Indiana till predominates over sand and gravel as far east as the meridian of Valparaiso. From this line northeastward there is a decided change in constitution, and sand and gravel predominate over till. The prominent portions of the morainic system appear to contain a larger proportion of sand and gravel than the lower portions. This is true not only of Porter and Laporte counties, Indiana, but of Berrien, Van Buren and Allegan counties, Michigan. It is not rare to find well sections in these prominent portions of the morainic system which penetrate nothing but sand and gravel in a depth of 100 feet or more. Till, however, is usually present in small amount on these elevated tracts. In Lake and Porter counties, Indiana, the till has considerable depth on the north or inner border of the morainic system, but is underlain at slight depth by sand and gravel on the southern border of this system, thus forming a phase intermediate between the gravelly, sandy portion to the east and the till portion to the west.

The cause for the marked difference in constitution displayed by this morainic system can as yet only be conjectured. The writer's attention was called by Mr. F. B. Taylor to the coincidence of the gravelly and sandy portion of the morainic system with the extent of prominent dunes along the shore of the lake, and the suggestion was made that the great abundance of sand in this portion of the moraine may be due to the incorporation of dune material which had been blown into that region during an interglacial interval. Some doubt concerning this view is raised by the absence of sandy material in the other moraines formed on the southeast border of Lake Michigan. This, however, may not be a fatal objection, since the invasion which formed the Valparaiso moraine may have gathered up the entire deposit of dune material and may have been followed so closely by the deposition of the later moraines that no opportunity for the formation of dunes was afforded. In the writer's opinion a cause for the sandy and gravelly constitution may be found in the relation of the Lake Michi-

gan and Saginaw lobes, since the sandy and gravelly phase is confined nearly to the portion of the Lake Michigan belt closely associated with the Saginaw lobe. These causes are not antagonistic and may supplement each other; possibly other causes will be found to have been effective in producing the large amount of sand and gravel.

The surface of the moraine is strewn with a moderate number of bowlders. They are mainly crystalline rocks of Canadian derivation. The great majority fall below 3 feet in diameter. There are, however, occasional immense bowlders of Corniferous limestone and of sandstone found on the Michigan portion of the morainic system. In western Bangor Township, Van Buren County, sandstone bowlders are scattered over a tract about a mile and a half from north to south and scarcely half a mile in width. They are most abundant in secs. 16 and 17, on a prominent knoll which is situated on the border of the section. One bowlder on this knoll was made use of to build a large stone house in Hartford, Michigan. Two other large bowlders still remain on the knoll, the larger one 24 by 24 by 21 by 21 feet on the sides; the other 24 by 30 by 18 by 15 feet. They each stand 6 or 8 feet above the surface and extend an unknown distance beneath. The owner of the farm on which they are situated states that he dug down 6 feet by the side of one of them and did not reach the bottom. Similar bowlders are found in Bloomingdale Township, scattered over a belt nearly 3 miles in length and scarcely 100 rods in width. The north end is near the Base Line in sec. 4, and the south end in sec. 17, about a half mile west of Bloomingdale station. They abound on the most prominent points along this line, but are seldom found on the low land between the knolls. They are embedded in the ground at various angles, some standing nearly on edge. The largest ones measure 15 or 20 feet in diameter and stand 6 or 8 feet above the surface. It is reported that similar large sandstone bowlders occur in sec. 33, Bloomingdale Township, but these were not visited by the writer. These sandstones are mainly of red or pink color, but a few specimens are brown. A large limestone block was noted in sec. 11, Hartford Township, Van Buren County. It had been uncovered to the extent of about a rod square, and had been quarried to a depth of about 3 feet, yet neither its lateral limits nor its bottom had been reached. A bowlder of the same kind of limestone occurs on the base line between Bloomingdale and Cheshire townships, less than a mile west of the north

end of the sandstone belt above noted. This is about 5 feet square and 18 to 20 inches in thickness. Probably other large bowlders occur in this region, for no exhaustive search was made. The sandstone bowlders appear to be of northern derivation, though the exact locality and geological horizon of the beds from which they came have not been determined. One of the limestone bowlders in Van Buren County, examined by Dr. Alexander Winchell, is referred by him to the Corniferous. Possibly the outcrop of this rock is to the north beneath Lake Michigan. They are now at an elevation of 150 feet above the level of the lake in a district where the drift deposits are shown by the wells to be very thick.

In this connection it may be remarked that one of these limestone bowlders in Van Buren County has been referred to by Winchell in evidence of a northward transportation of drift.[1] This bowlder is mentioned in connection with others noted in Hillsdale, Jackson, and Lenawee counties, Michigan, and all are supposed to have been transported northwestward by an ice movement from the border of Lake Erie. Winchell was probably correct in his interpretation of northward transportation into the counties in southeastern Michigan, for the Lake Erie glacier would very naturally have given limestones on the north border of the lake a northward transportation, but the Erie ice movement can scarcely be supposed to have extended to Van Buren County.

It may naturally be inferred that strong wells are difficult to obtain in the portion of this morainic belt where till greatly predominates over sand and gravel. It is found, however, that, with the exception of a small section embracing southern Lake, northwestern Cook, and northern and eastern Dupage counties, wells suitable for supplying stock and dairy farms may be obtained at convenient depths. In Will County wells seldom reach a depth of 100 feet because of abundance of water-bearing sand and gravel at less depth. The same is true of Lake and Porter counties, Indiana, and of much of Cook and Lake counties, Illinois. In the district where wells are difficult to obtain, it is often necessary to sink to a depth of 150 feet or more. This carries the wells into the older drift sheets beneath the Wisconsin drift. Well sections obtained in the Illinois portion of this morainic system are presented in the discussion of wells below; those in the Indiana

[1] Am. Jour. Sci., 2d ser., Vol. XL, 1865, p. 331.

portion are discussed in another report;[1] the wells of the Michigan portion are taken up in some detail at this point. The discussion begins with Allegan County, at the north end of the district examined, and proceeds to consider areas lying southward.

A well on the farm of G. H. Hill, 2 miles west of Allegan, on the elevated sandy land south of the Kalamazoo River, penetrates sand and gravel slightly cemented near bottom, 63 feet, and terminates at 65 feet in a sticky blue clay, apparently pebbleless. Another well on the same farm penetrated 50 feet of sand and gravel and entered a similar sticky blue clay 4 feet. This clay is perhaps a silt deposited in advance of the ice invasion by which the morainic system was formed.

Immediately north of these wells in the Kalamazoo River Valley, wells are 20 to 22 feet in depth and are mainly in a loose sand with some cemented gravel. In some wells there is near the bottom an oily, sticky, blue clay, 8 feet or more in depth, and occasionally a yellowish brown till is encountered. Three prospect borings for oil at Allegan penetrate about 240 feet of drift, of which the upper 120 feet is sand and clay, and the lower 120 feet mainly gravel.[2] In the Kalamazoo Valley, at the waterworks in Allegan, a well has been sunk to a depth of 180 feet in partially cemented gravel with a very little till. The bluffs of the river at Allegan are about 60 feet in height and present the following section in the south part of the city:

Section at Allegan, Michigan.

	Feet.
Loose gravelly sand	20–25
Cemented gravel	20–22
Loose sandy gravel	20

If this be added to the 180 feet of assorted material penetrated in the waterworks well it gives a section 240 feet in depth, nearly all of which is assorted material, fully two-thirds being cemented gravel. On the north side of the river, about a quarter of a mile west of the railway station, a blue silt is exposed up to within 20 feet of the top of bluff. To show equally great contrast in structure within a short range another well section is cited. It is on the west bluff of the Kalamazoo River, about a mile south of Allegan

[1] Wells of northern Indiana, by Frank Leverett: Water-Supply and Irrigation Papers, No. 21, U. S. Geol. Survey.

[2] See Geological Survey of Michigan, Vol. V, 1895, part 2, p. 45; also Pls. XXX–XXXII.

on the farm of A. Stedgman. This penetrates a few feet of yellow till, and is then in a blue-gray till to the depth of 100 feet, below which is a white quicksand about 80 feet in depth. Water was obtained in a gravel bed at the bottom of the quicksand.

A well on the moraine north of Allegan, sec. 11, Pine Plains Township, penetrates the following beds:

Section on moraine north of Allegan, Michigan.

	Feet.
Yellow clay loam	8–10
Blue-gray till	10
Cemented gravel	58–60
Depth	78

In some cases wells on the moraine in this vicinity penetrate till 35 to 40 feet. It is more or less oxidized, and, as a rule, is very pebbly. Below the till there is usually cemented gravel. In the low belt between the two till ridges north of Allegan along the line of the Lake Shore and Michigan Southern Railroad wells penetrate a slight depth of till of a yellowish blue color, somewhat pebbly, below which is a blue quicksand.

Mr. H. W. Austin, an experienced well borer residing at Allegan, finds that where there is till of a blue color much cemented gravel is seldom encountered, but there is a loose gravel or sand, sometimes a quicksand, beneath the till. When cemented gravel of considerable depth is overlain by till, the till is usually more or less oxidized, even to a depth of 30 or 40 feet.

East of Allegan is a till plain in which a deep boring having the following section was made on the farm of Chauncey Palmer. It was abandoned without obtaining water or reaching the bottom of the till:

Section in till plain east of Allegan.

	Feet.
Yellow till	4
Blue till, compact, with few pebbles	168
Gravelly clay	6
Blue till	38
Depth	216

There are shallow flowing wells on the till plain east of Allegan. One in sec. 21, Watson Township, on the farm of A. Alexander, is 20 feet in depth and penetrates slightly oxidized blue till, obtaining water in gravel. One in sec. 20, Watson Township (T. 2 N., R. 12 W.), on the farm of S.

Van Dusen, 40 feet in depth, penetrates a sticky blue clay almost pebbleless and obtains water from a gravel. There are three flowing wells in sec. 34, Watson Township, none of them exceeding 50 feet in depth, of which the major part of the section was gray till. A flowing well near the south line of Watson Township, 1½ miles east of Abronia, on the farm of Martin Hewer, penetrates a blue-gray till 87 feet and obtains its flow from a bed of sand. The source of supply for these wells is probably in the neighboring high parts of the Valparaiso morainic system.

On a very elevated portion of the moraine in sec. 9 of the same township (T. 2 N., R. 12 W.), where the elevation is about 150 feet above the boring at Mr. Palmer's, a well penetrated dry sand and gravel to a depth of 125 feet, and beneath this 25 feet of cemented gravel interbedded with reddish clayey gravel. On this elevated tract several wells 80 to 120 feet in depth are largely in assorted material. They contain thin beds of bluish clay alternating with thick beds of sand and gravel.

North of this elevated tract, on the till plain which sweeps around its western end, there are several flowing wells. They are in the southern part of Hopkins and western part of Wayland townships (T. 3 N., R. 12 W. and T. 3 N., R. 11 W.). Their surface elevation is about 100 feet lower than the general elevation of the bordering moraine, and 150 to 175 feet lower than the highest points. They range in depth from 40 to 165 feet. They are mainly through blue till, beneath which is a hard gray clay.

A well near Ohio Corners, about 2 miles north of Hopkins, penetrates the following beds:

Section in well near Ohio Corners, Michigan.

	Feet.
1. Water-bearing gravel	24
2. Blue-gray till	66
3. Gravel and water	5
4. Limestone (?)	40
5. Blue sandy clay (shale?)	111
Depth	246

At the bottom of this clay solid rock about a foot in thickness was found and below this salt water was struck. If no mistake was made by the well borer in identifying "No. 4" as limestone, the rock here attains an elevation of at least 650 feet above tide, an unusual elevation for this latitude so near the east shore of Lake Michigan. Perhaps "No. 5" is a shale.

On the overwash gravel plain in western Martin Township, Allegan County (T. 2 N., R. 11 W.), a well in the northern part of sec. 20 penetrates sand and gravel 50 feet; beneath this a hard blue bowlder clay 100 feet. The well was abandoned without reaching the bottom of the clay. A well in the southern part of sec. 6 penetrates the following beds:

Section in well in Martin Township, Allegan County, Michigan.

	Feet.
Loamy clay and gravel	5–6
Cemented gravel	15
Blue-gray till	12–15
Gravel	6–8
Quicksand	6–8
Gravelly clay, slightly oxidized	30
Blue-gray till	30
Gravel	1
Depth	112

Many wells on this overwash plain 40 feet in depth are entirely in sand and gravel, after passing through the soil and a slightly cemented gravelly and loamy clay 2 to 4 feet in depth.

In an excavation made by the Grand Rapids and Indiana Railroad in the southern part of sec. 17, Martin Township (T. 2 N., R. 11 W.), there is an exposure 25 feet in depth revealing a mass of cobble, bowlderets, and occasionally bowlders, in a bed of fine gravel. The pebbles are much rounded, and in places are held together by a calcareous cement. A large part of them are granites or other metamorphic or igneous rocks. One-fourth to one-third are limestones, slate, and other local rocks.

A well on Mr. Knickerbocker's farm, in sec. 2, Trowbridge Township (T. 1 N., R. 13 W.), penetrates the following beds:

Section in well in Trowbridge Township, Allegan County, Michigan.

	Feet.
Soil and sand	20
Soft blue clay with few pebbles	4
Cemented gravel	7
Loose gravel	15
Blue clay apparently pebbleless	2
Water-bearing sand	3
Depth	52

A well 80 rods west from there, on Mr. Ipe's farm, 80 feet in depth, passed through gravelly sand with very little clay admixture. Two miles

east, in sec. 6, Otsego Township, James Henderson has a well 80 feet deep almost entirely in till, as follows:

Section in well in Otsego Township, Allegan County, Michigan.

	Feet.
Yellowish till	30
Blue-gray till	50
Gravel at bottom.	
Depth	80

Southwest from Allegan in Cheshire Township much sand occurs, but not in level tracts as on the Pine Plains. The sand has a billowy surface and associated with the sandy knolls are knolls containing much till.

A well in sec. 19, Cheshire Township, on the farm of W. W. Spencer, penetrates:

Section of Spencer well in Cheshire Township, Allegan County, Michigan.

	Feet.
Soil and gravelly clay loam	4
Sand	6
Cemented gravel	5
Gravelly sand	93
Depth	108

This well is on a prominent knoll nearly 100 feet higher than a swamp 80 rods south from the well and 50 feet above the general elevation of the moraine east of it. Wells in the adjoining section on the east range from 20 to 35 feet in depth and penetrate mainly sand and gravel, the only clay being a yellowish clay loam near the surface. In the northern part of Cheshire Township there are several wells which are largely in till. One in sec. 9, 118 feet in depth, is mostly in a sandy blue clay, but the exact section was not preserved. A well in the southeastern part of the same section, 36 feet in depth, penetrates the following beds:

Section of well in Sec. 36 Cheshire Township, Allegan County, Michigan.

	Feet.
Yellowish sandy till	20
Blue sandy till	14
Water-bearing sand	2

This till tract extends northeast nearly to the city of Allegan, lying between the outlet of Littlejohn Lake and the Kalamazoo River.

In the southern part of Cheshire Township, Allegan County, and northern part of Bloomingdale Township, Van Buren County (T. 1 S., R. 14 W.), wells penetrate 20 to 35 feet of till, and are then in sand for

20 feet or more. A well on the farm of Hon. H. Howard, in sec. 4, Bloomingdale Township, has the following section:

Section of Howard well in Bloomingdale Township, Allegan County, Michigan.

	Feet.
Loamy clay, with much sand and gravel	12
Bluish-brown till	15
Yellowish-gray sand	20
Cemented gravel	3
Coarse yellow sand	12
Depth	62

A well across the road, on J. Howard's farm, differs in section from the one given, having no cemented gravel. Its depth is 54 feet. Several wells near Eagle Lake, in Cheshire and Bloomingdale townships, 50 to 60 feet in depth, have till in their upper portion and sand in the lower. East of Eagle Lake is a heavy deposit of till, one well being almost entirely in blue-gray till to a depth of 112 feet, obtaining water in gravel at 118 feet. In sec. 20, T. 1 N., R. 15 W., at Lee Station, which is situated at the southern border of the "Pine Plains," on the Chicago and Western Michigan Railroad, a well 120 feet in depth, in which water rises nearly to the surface, has the following section:

Section in well at Lee Station, Chicago and Western Michigan Railroad.

	Feet.
Sand	8
Hard pebbly blue clay	30
Bluish quicksand	50
Blue-gray till	28
Gravel	4
Depth	120

A well at Grand Junction, in Van Buren County, penetrates the following beds:

Section in well at Grand Junction, Michigan.

	Feet.
Soil and dry yellow sand	25
Damp sand of gray color	48
Sand and gravel at bottom	5
Depth	78

Many wells in Geneva Township, 2 to 5 miles west of Grand Junction, are in till to a depth of 25 feet, but among these are wells largely in sand or gravel. East from Grand Junction for several miles the well sections are largely sand. Near Columbia Station, on the farm of Mr. Reece,

a well which was in process of boring at the time of my visit shows the following section:

Section near Columbia Station, Michigan.

	Feet.
Yellow sand	20
Soft blue clay, apparently pebbleless	18
Bluish sand, exceedingly fine	140
Depth	178

This sand is so fine that it can not be screened by the pump strainer, and renders the water unfit for use.

In the vicinity of Great Bear Lake, south of Berlamont Station, there are several wells 100 feet or more in depth. One on a hill three-fourths mile west from the north end of the lake passes through 100 feet of dry sand and gravel, then enters water-bearing sand to a depth of 16 feet. Another south of the lake in western Bloomingdale Township was dug 100 feet through sand and gravel without obtaining water. A well southwest of the lake, in sec. 25, Columbia Township, on a hill rising 100 feet above the lake, is 125 feet in depth and largely in dry sand and gravel. Between Great Bear Lake and Bloomingdale wells are sunk mainly in till, both yellow and blue, but are only 40 to 60 feet in depth.

A well 2 miles south of Bloomingdale, on J. G. Miller's farm, is 110 feet deep, passing through blue-gray till nearly the whole depth. As a rule Bloomingdale Township is underlain by till to an average depth of 40 feet, the only notable exception being the eastern tier of sections, where wells are largely in sand and gravel. This tier of sections is more elevated than the remainder of the township.

A well at Mr. Merrifield's, 1½ miles north of Bloomingdale, presents the following exceptional section:

Section in well near Bloomingdale, Michigan.

	Feet.
Soil and dry yellow sand	20
Quicksand	14
Blue-gray till	8
Cemented gravel	12
Yellowish till	20
Quicksand of gray color	6
White sand with water	10
Water-bearing gravel	1
Depth	91

A well 3 miles south of Gobles, in Waverly Township, on a prominent point called Covey Hill, is 109 feet in depth, and the entire section is made

up of sand beds alternating with thin layers of cemented gravel. Wells in Gobles, and for a mile or two north and south from this village, are from 50 to 60 feet in depth. They penetrate, just below the soil, a crust of cemented sand, gravel, and clay, called "hardpan," about 2 feet in thickness, beneath which are alternate beds of sand and gravel, loose and dry as a rule, but cemented slightly in places. Usually a cemented layer is passed through just above the water. Wells in the gravel plain from 1 to 3 miles northeast of Gobles pass through 2 to 5 feet of hard, pebbly, reddish clay called "hardpan." Below this is sand, loose gravel, and cemented gravel. Wells are about 40 feet in depth and seldom penetrate any till or clay except that just beneath the soil.

A well in the northern part of sec. 18, Almena Township (T. 2 S., R. 13 W.), on the farm of Robert Clark, is 86 feet in depth, and has the following section:

Section of Clark well in Almena Township, Van Buren County, Michigan.

	Feet.
Loamy sand	14
Quicksand	2
Blue-gray till	40
Cemented gravel	14
Fine sand	16
Total	86

Gravel and water at bottom.

A large part of Waverly Township is underlain by till. Nearly half of the township is swamp land with very few inhabitants, but the portion not swampy (northeastern part) has wells 35 feet or more in depth almost entirely in till. This till is yellow or oxidized to a depth of at least 15 feet. An elevated tract in the northwestern part of the township has a loamy clay 2 to 4 feet and occasionally 10 to 12 feet in depth, below which is a reddish-yellow till. Wells are only 20 to 25 feet in depth.

There is a small flowing well district in the swamp along the Pawpaw River, in the southwestern part of the township. All the wells of which records were obtained are in the southern part of sec. 30. They are each about 50 feet in depth. In one well the water rises nearly 10 feet above the surface, but in the others only 1 to 4 feet. They penetrate a slightly pebbly blue clay nearly the whole depth, there being scarcely any yellow clay even at the surface.

On the elevated tract north of Pawpaw River, in Lawrence, Hartford, and Arlington townships (T. 3 S., Rs. 15 W. and 16 W., and T. 2 S., R. 15 W.), a considerable portion has but 6 or 8 feet of till, beneath which is dry sand or gravel. In some cases wells are sunk 100 feet in this sand and gravel before reaching water, but the majority of them obtain water at 40 to 50 feet. On the elevated land immediately north of the village of Lawrence there is much sand at the surface. Wells are often 20 to 40 feet in sand. In some places the sand is underlain by 10 to 20 feet of bluish till, and this in turn by dry sand or gravel, becoming water-bearing toward the bottom; beneath this lower sand is a blue till of various depths.

Wells in southern Arlington Township, near the northern part of the elevated tract, are frequently 80 feet and occasionally 160 feet in depth. A well in sec. 23, 162 feet in depth, penetrates:

Section of well in sec. 23, Arlington Township, Van Buren County, Michigan.

	Feet.
Reddish-brown till	40
Quicksand	10
Blue-gray till	110
Gravel	2
Total	162

In the same section is a well 80 feet in depth, which penetrates the following beds:

Section of well in sec. 23, Arlington Township, Van Buren County, Michigan.

	Feet.
Dry sand	40
Cobble and gravel	15
Sand of gray color, streaked with red, containing limestone concretions	25
Total	80

As a rule, there is 12 to 15 feet of reddish-brown till above the sand and occasionally 40 to 50 feet, but in places it is wanting entirely, as in the above section. A well in sec. 20 has the following section:

Section of well in sec. 20, Arlington Township, Van Buren County, Michigan.

	Feet.
Yellowish-brown till	10
Cemented gravel	8
Dry sand and gravel, with cemented gravel near bottom	35
Brownish till, with thin beds of cemented gravel and quicksand	30
Water-bearing gravel	2
Depth	85

A well on sec. 21, one-half mile east of the above, is 125 feet in depth and is almost entirely in sand and gravel. This well is on a prominent knoll. So far as observation was extended, these knolls quite uniformly show a great depth of sand and gravel, with but little till, and that, too, when till is found on the adjacent lower lands.

On the elevated land north of Hartford, in sec. 11, Hartford Township, at a height of 85 feet (aneroid) above the flood plain of Pawpaw River, on the farm of Samuel Keine, a well 87 feet in depth penetrates:

Section in Keine well north of Hartford, Van Buren County, Michigan.

	Feet.
Gravelly sandy clay	10
Yellowish till	12
Cemented gravel with thin clay beds	60
Loose gravel with water	5
Total	87

A well across the road was sunk to a depth of 160 feet. For a depth of 80 feet its section is similar to the above; below this there is a bed of blue bowlder clay nearly 80 feet thick, which is underlain by water-bearing gravel. It was on Mr. Keine's farm, at a level about 35 feet lower than the surface at the well, that the huge limestone bowlder noted above (p. 357) was found.

In Bangor Township and in the vicinity of Breedsville, in Columbia Township, deep wells are rare, the usual depth being but 25 to 30 feet. In some cases the wells are largely in till, but in others the section is principally gravel. There is but little sand on the surface in Bangor Township, compared with that in Columbia Township, and it is exceptional to pass through much sand in sinking a well unless it be on a high knoll. The deepest well in this township of which a record was obtained is in sec. 17, on the highest knoll in the western part of the township, and is interesting, since it is but a few rods distant from one of the large sandstone bowlders noted above. The following is the well section:

Section of well in sec. 17, Bangor Township, Van Buren County, Michigan.

	Feet.
Yellowish till	5
Dry sand	15
Coarse sand with water	3½
Fine sand	7
Brownish clay	8
Sand	66
Depth	104

A prominent knoll about a mile east of Bangor, rising 125 feet above the station of the Chicago and West Michigan Railroad, or 775 feet above tide, contains much fine sand which has been used in the iron furnace in Bangor as molder's sand. There are gravel beds interstratified with it. The exposure does not show the deeper structure of the hill.

In Watervliet Township and in western Hartford Township the western portion of the morainic belt has a deposit of till which is penetrated to a depth of 20 to 40 feet in wells; but in eastern Hartford and Lawrence townships the structure changes on rising to the higher portions of the moraine, and wells are in sand or gravel much of their depth. There is, however, on the lowland along Pawpaw River from Hartford to Watervliet a sandy belt a mile or more in width in which wells penetrate sand or gravel to a depth of 20 to 40 feet without encountering till. At Watervliet this sand belt is very narrow, wells 80 rods south from the railway station penetrating much till. The sand and gravel is confined to a plain along the river, which stands at about the level of the highest beach of Lake Chicago. The ridges and undulatory tracts both north and south from this plain contain much till.

The rolling belt southwest from Coloma has a great depth of sand, so that wells 35 to 50 feet in depth penetrate little else. In the village of Coloma wells encounter a variety of beds, of which the following section of a well at Mr. Abram Smith's may be taken as representative:

Section of well at Coloma, Berrien County, Michigan.

	Feet.
Clay loam of yellow color	8
Dry gravel and sand with bowlderets and bowlders embedded	13
Cemented gravel	8
Blue clay, apparently pebbleless	9
Depth	38

Wells on the ridge on the south side of the Pawpaw River, between Coloma and Watervliet, disclose much variation in structure. One well may be largely in till, another on the same farm principally in sand or gravel, while a third may have both assorted and unassorted drift. The surface is more uniformly coated with a clay loam east of Coloma than it is southwest. A well on the north side of Pawpaw River, near Pawpaw Lake, on the farm of Mr. Huntoon, penetrates:

Section in well near Pawpaw Lake, Michigan.

	Feet.
Yellowish till	10
Blue-gray till	10
Dry sand	20
Water-bearing gravel	4
Depth	44

A well at Hillside stock farm, on the north side of Pawpaw River, opposite Watervliet, penetrates till, principally of a blue-gray color, to a depth of 40 feet. A well on the northwest side of Pawpaw Lake, in the east part of sec. 9, 125 feet deep, penetrates till 120 feet.

In the portion of Hartford Township east of the village, wells are in sand and gravel on the elevated land, while west from the village the elevated tracts are covered with a quite heavy deposit of till. Pine Creek seems to mark the division line, there being more sand and gravel east of the creek than west of it.

A well in sec. 17, Lawrence Township, on a prominent portion of the moraine 100 feet or more above Pawpaw River, penetrates the following beds:

Section of well in sec. 17, Lawrence Township, Van Buren County, Michigan.

	Feet.
Yellowish till	10
Dry sand	70
Quicksand	40
Blue clay; no pebbles observed	40
White dry sand	70
Depth	230

A well in the southwestern part of the same section, 103 feet in depth, penetrates only 8 feet of till, the remainder being sand.

A well in the northeastern part of sec. 20 of the same township, 80 feet in depth, penetrates but 7 feet of till. The sand is coarse at top and becomes finer below. In the lower part of the bed it was fine as flour. The pipe was drawn up to within 57 feet of the surface, where the sand was sufficiently coarse to be screened by the pump strainer. Several other wells in the southwestern part of Lawrence Township are characterized by a slight depth of yellow till underlain by a great depth of sand.

T. O. Sweet, a well borer residing at Lawrence, states that wells in the village of Lawrence are usually 25 to 40 feet in depth and penetrate the following beds:

Generalized section of wells at Lawrence, Michigan.

	Feet.
Reddish till and sandy clay	7–18
Yellow till	3– 7
Quicksand	9–14
Blue-gray till at bottom.	

In some cases the quicksand extends to a depth of 40 feet or more, so that its bottom is not reached.

On the elevated land south of Lawrence there is 12 to 20 feet of yellowish till with sandy gravel interbedded, and beneath this is a blue till mixed with blue quicksand. Wells in some cases penetrate this quicksand to a depth of 100 feet.

On the outer border of the moraine, in sec. 1, Lawrence Township, on the farm of Mr. Hutchins, a well 125 feet deep penetrated sand and gravel its entire depth and encountered many bowlders and bowlderets. A well at Mr. Whipple's, in the river valley half a mile north and about 120 feet lower at the surface than the preceding, penetrates a yellow till 12 to 15 feet, below which is blue clay, apparently pebbleless, penetrated to a depth of 25 feet. Mr. Whipple states that the valley of Pawpaw River, in northeastern Lawrence Township, is underlaid by clay of a blue color and also a blue quicksand. In one instance a well was driven into this quicksand 80 feet without reaching the bottom.

A well near the border of the Pawpaw Valley, 20 feet or more above it, on the slope of the moraine in the eastern part of sec. 11, Lawrence Township, has the following section:

Section of well in sec. 11, Lawrence Township, Van Buren County, Michigan.

	Feet.
Sand and gravel	18–20
Blue-gray till	48
Coarse sand and fine gravel	14
Depth	72

A well about 60 rods north from this, at nearly the same level, penetrated no thick bed of till, but instead alternate beds of clay and sand or clay and gravel to a depth of 76 feet.

A well on the border of the overwash apron in the southeastern part of sec. 12, Lawrence Township, penetrated coarse gravel and cobble 84 feet before striking water, and this well has the peculiarity of freezing over in winter. Probably the outside air has access through the spaces in the gravel and cobble beds to the water in the well.

Wells along the outer border of the moraine in southeastern Lawrence Township (T. 3 S., R. 15 W.) and northwestern Hamilton (T. 4 S., R. 15 W.) penetrate more till than do those nearer the Pawpaw River, many wells 25 to 40 feet in depth being largely in till, but there is occasionally a small tract in which no till occurs. In such a tract in sec. 5, Hamilton Township, there are two wells, each 110 feet deep, which penetrate sand and quicksand for 100 feet before reaching any gravel. A well in sec. 2, Keeler Township, 85 feet in depth, is entirely in sand, while on adjoining farms wells penetrate a considerable depth of till.

The overwash apron which borders the moraine in Pawpaw, Lawrence, Hamilton, and Keeler townships (Ts. 3 S., R. 14, 3 S., R. 15, 4 S., R. 15, and 4 S., R. 16), Van Buren County, has wells 25 to 70 feet deep which seldom penetrate any till, but are in assorted material, usually gravel, their entire depth. There is a hardpan of slightly cemented gravelly clay loam 2 feet or more in depth just beneath the soil over much of this overwash apron. At Keelerville wells are obtained at 30 to 40 feet. They penetrate 15 feet of loose gravel and sand just beneath the hardpan, then 12 to 15 feet of slightly cemented gravel, and strike water in uncemented gravel.

On the moraine southwest of Keelerville are wells 45 to 100 feet in depth which penetrate but little till as compared with those northeast of the town. A well 5 miles distant, in the northwestern corner of Cass County, was driven to a depth of 190 feet and passed first through a bed of gravel, then through 125 feet of quicksand.

Immediately west of this elevated gravelly portion of the moraine which passes from Sister Lakes across the northwestern corner of Cass County is a tract of land along Pipestone Creek whose surface is 100 to 130 feet lower than the moraine, and in a belt of this lower tract between Pipestone Creek and the higher land extending for 4 or 5 miles south of Pipestone Lake several flowing wells have been obtained. Information concerning them was given by Robert Kingsley, a well borer, who has been employed in sinking the wells. They usually range in depth from 80 to 125 feet, and are mainly through till, yellowish brown for 15 to 20 feet and

of blue-gray color 65 to 100 feet. Beneath this till there is usually a ferruginous crust a few inches in thickness which caps the water vein. The water rises in each well 8 to 10 feet above the surface and flows several gallons per minute. It is slightly chalybeate.

Near the corner of secs. 1 and 2, 11, and 12, Pipestone Township, are two flowing wells, one 56 feet and the other 68 feet in depth. There are two wells on the south side of the SW. ¼ of sec. 11 which are 75 to 80 feet in depth and flow 10 to 15 gallons each per minute. A well in the southwestern corner of sec. 22 only 24 feet in depth flows about 5 gallons per minute, the water rising but 2½ feet above the surface. A well in the NW. ¼ of sec. 27, about 25 feet deep, flows 3 gallons per minute, the water rising 2 to 3 feet. A well in the SE. ¼ of sec. 2, 36 feet in depth, flows 15 gallons per minute at an elevation of 3 feet above the surface. It penetrates a yellowish-brown till nearly to the water vein. In the SW. ¼ of sec. 2 a well 150 feet in depth flows but 3 gallons in five minutes. This is decreasing in flow. It is the pioneer well and began flowing about 1877.

The surface of this flowing well district is gently undulatory, with frequent oscillations of 10 to 15 feet in 20 to 30 rods. The wells as a rule are on low land not more than 10 or 15 feet above the level of Pipestone Creek.

Northwest of this flowing well district and uniting with the elevated tract which forms its eastern boundary is a tract of high land which is characterized by a large amount of sand. Many wells are 60 to 80 feet or more in sand, but in the midst of the sandy belt are spots where a considerable depth of till is found. For example, a well in the northwest corner of sec. 13, Bainbridge Township (T. 4 S., R. 17 W.), penetrates:

Section of well in sec. 13 Bainbridge Township, Berrien County, Michigan.

	Feet.
Brownish-yellow till	10–12
Blue-gray till	15
Water-bearing sand at bottom.	8–10
Depth	37

A well on the south side of sec. 12 of the same township penetrates:

Section of well in sec. 12 Bainbridge Township, Berrien County, Michigan.

	Feet.
Brownish-yellow till	8–10
Blue-gray till, with thin beds of quicksand	110
Gravel	5
Depth	125

This till tract fronts the south border of a swamp for 2 or 3 miles. The till extends back but a short distance toward the south, soon giving place to sand.

A very small tract underlain by till is found near the corner of secs. 14, 15, 22, and 23 of this township (Bainbridge). It is less than a square mile in extent. A well in the southwestern corner of sec. 14 penetrates:

Section of well in sec. 14 Bainbridge Township, Berrien County, Michigan.

	Feet.
Yellowish till	6
Blue-gray till	110
Gravel at bottom of well.	
Depth	116

A mile west from here, at Bainbridge Center, wells are almost entirely in sand to a depth of 60 feet. In the sand are thin beds of slightly cemented gravel. This sandy tract extends west a mile or more from Bainbridge Center and nearly as far north. A well in the western part of sec. 10, on the farm of A. Woodruff, penetrates:

Section of Woodruff well in Bainbridge Township, Berrien County, Michigan.

	Feet.
Brown sand	5
Brownish-yellow till	12-14
Gray sand, with occasional nodules and clay balls	48-50
Brownish till, very hard	12
Gravel and sand with water at bottom.	
Depth	81

A well across the road, 75 feet in depth, has a similar section.

In western Bainbridge and eastern Benton townships (Ts. 4 S., R. 17 W., and 4 S., R. 18 W.) wells vary much in the character of their section, some being almost wholly in till, others penetrating little beside gravel and sand, and this is often true where the whole surface appears sandy.

In the northeastern part of Bainbridge Township, about 3 miles due south of Watervliet, are three flowing wells. They are only 16, 28, and 40 feet deep. Most of their section is in blue-gray till, and the water comes, it is said, from caverns in the clay. The water, which is quite chalybeate, rises 2 to 4 feet above the surface.

In the portion of the Valparaiso moraine in Berrien County south from the latitude of St. Joseph, Michigan, no records of wells were collected. The portion east from St. Joseph River apparently consists largely of sand

and gravel. In the portion west of the river till apparently predominates over sand and gravel, though the inner border is in places quite sandy.

CHARACTER OF THE OUTWASH.

The position of the Valparaiso morainic system is favorable for the discharge of water from the western and southern borders and to some extent from the eastern border. On the west the Fox, Dupage, and Des Plaines rivers, and small tributaries of the Des Plaines, lead directly away from the border of the morainic system, while on the south the Kankakee and its tributaries afford a line of discharge toward the west. On the east the streams now draining the border of this morainic system are tributary to rivers which flow through it into Lake Michigan, but it seems probable that for at least a portion of the time of the formation of the Valparaiso morainic system the drainage along Dowagiac River and also much of the St. Joseph River was tributary to the Kankakee instead of the lower St. Joseph River.

Along each of the main valleys which border the morainic system, or lead away from it, a large amount of gravelly material has been deposited. Taking these valleys in turn, beginning with Fox River and passing south and east, the features are as follows:

On Fox River, from the Wisconsin line southward nearly to the south line of Lake and McHenry counties, there are broad marshes underlain by sand and silt, and the stream has very little fall. Professor Rolfe's barometric survey indicates that there is a fall of but 30 feet in the 30 miles occupied in crossing these counties. In southeastern McHenry County heavy deposits of gravel and cobble set in, which lead down the valley in the form of terraces through the entire length of Kane County, a distance of 30 miles. The stream in this distance makes a descent of 125 feet, while the gravelly terraces make an even greater descent, their elevation at Elgin being nearly 100 feet and at Aurora only 40 to 50 feet above the stream. Heading as these gravel deposits do near the point where the Valparaiso moraine leads away from the Fox River Valley, and standing as they do above the marshy tracts along the portion of the valley immediately to the north, there seems to be little question that they represent an outwash from the ice sheet. The gravel is of medium coarseness throughout the greater part of its depth, but in places the surface portion consists

of cobble and coarse gravel. The belt occupies a width of a mile or more and the gravel is in places built up 60 to 75 feet. In other places it has a depth of only 10 or 20 feet. The average depth is probably not less than 40 feet.

On the west Dupage River, which throughout much of its course follows the outer border of the Valparaiso morainic system, there are deposits of gravel and cobble occupying a belt a mile or so in width, which connect at the south with a still broader belt of gravel. On the slopes of the moraine immediately east of this stream there are numerous gravelly knolls, which connect with the plain of gravel on the borders of the river in such manner as to indicate that they should be included with the glacial drainage, though they suffered so little transportation as to make the term "outwash" seem scarcely appropriate. The lower Dupage River appears to have been an avenue of discharge, not only for glacial waters from the Upper Dupage but also from the neighboring section of the Des Plaines River, as indicated below.

On the Des Plaines Valley the gravel filling apparently reached such a height that a delta-like system of streams was formed in the vicinity of Joliet, some of which were thrown across the low divide on the west into the Dupage River. Along the courses of the glacial streams, well-defined valleys were formed which are now occupied by marshes and insignificant tributaries of the Des Plaines and Dupage. The position, size, and relation of these abandoned valleys are set forth on the Joliet topographic sheet of this Survey. One valley occupied by the Isle la Cache Creeks has a summit level slightly above the 600-foot contour; another, drained by Mink Creek, has a summit level about 620 feet; a third, now largely undrained but connecting at the west with Rock Run, was cut down to about 575 feet. The one drained by Mink Creek seems to have been cut no lower than the upper limit of the gravel filling on the neighboring portion of the Des Plaines, but the others were cut a few feet below the level of that filling.

On the immediate outer border of the main ridge of the Valparaiso morainic system, near Romeo, the gravel filling reaches about 620 feet, and this appears to be the head of the gravel, though the great excavation subsequently made by the Chicago Outlet leaves the question of the precise head somewhat uncertain. Upon passing down the Des Plaines the gravel filling shows a marked descent. At Joliet Mound, 2 miles below Joliet, it

has fallen to 580 feet and at Channahon to 570 feet, a fall of 50 feet in a distance of about 20 miles. There is a corresponding fall on the lower Dupage, the surface of the gravel in the vicinity of Plainfield being about 610 feet, at Grinton 590 feet, and at Channahon 570 feet.

The deposits along the Dupage and Des Plaines rivers consist in the main of coarse gravel and cobble, much of the finer material having been swept away by the strong current. Excellent exposures are to be seen in the gravel pits near Plainfield on the Dupage, and in numerous small gravel pits along the border of the Des Plaines both above and below Joliet. One of the largest on the Des Plaines is found in an island-like remnant of the old terrace known as Joliet Mound, about 2 miles below the city of Joliet, on the west side of the river. At the southeast end of this mound the following section is exposed:

Section of Joliet Mound, Will County, Illinois.

	Feet.
Surface coating of silty clay	1–4
Coarse gravel and cobble	10–12
Sandy gravel of medium coarseness, cemented in places	25–30
Fine sand or loam	4
Blue pebbleless clay, laminated, calcareous	8–10
Bowlder bed, containing clay balls and a sandy clay matrix, extending to river level on east side of mound, but underlain at slight depth by limestone at west side	5–20

It is thought that the bowlder bed may be a result of interglacial erosion of a till sheet. The blue pebbleless clay which overlies it is apparently a still-water deposit, formed perhaps before the ice sheet had reached such a stage of melting as to produce vigorous drainage. The upper member appears to indicate a deposit by a stream whose vigor was greatest toward the close of deposition, for at the top the cobble is swept almost free from sand. The change, however, may have been brought about by shifting of the main current of the stream, the coarse material being deposited over portions of the bed which had before been outside the main current. As only occasional remnants of this gravel filling are preserved, it is impossible to determine the original variations in coarseness in a section passing across the valley.

The deposits of gravel along this valley terminate very abruptly at the south, near Channahon, there being only a fine sand on the plain in the Morris Basin at the head of the Illinois. This feature is apparently due to the presence of a lake in the low country about the head of the Illinois

River. The beaches of this lake and its western discharge through the Marseilles moraine down the Illinois have already been discussed. The level of the beaches corresponds so nearly with that of the upper limit of the valley filling at Channahon that the latter may, with some confidence, be considered a delta-like accumulation at the north border of the lake.

It is probable that each of the small tributaries of the Kankakee, which head in the Valparaiso moraine, and also eastern tributaries of the Des Plaines, afforded lines for escape of glacial waters, but the writer has not examined these valleys with sufficient thoroughness to determine the effect of the glacial waters. On the valley of Hickory Creek, which enters the Des Plaines at Joliet, a gravel filling is conspicuous from the outer border of the main moraine in sec. 17, New Lenox Township, to the mouth of the creek. At its point of connection with the moraine it has a gently undulating surface, but about a mile west from the moraine the surface becomes plane. The gravel is built up nearly to the height of the bordering till plain, and stands 60 to 70 feet above the present stream.

The headwater portion of the Kankakee River leads through a gravel plain which descends toward the river from moraines on either side. On the north side the gravel plain connects with the Valparaiso morainic system, while on the southeast it connects with the Maxinkuckee moraine of the Saginaw lobe. In the vicinity of Laporte, Indiana, the gravel plain which is connected with the Valparaiso morainic system attains an elevation of fully 800 feet above tide on the immediate borders of the moraine. This great altitude, however, is apparently maintained for only a short distance, for the railway surveys show that there is a descent in it along the border of the moraine, both toward the northeast and the southwest, as well as a descent in passing southeastward from the moraine to the Kankakee River. The elevation of the gravel plain at New Carlisle on the borders of the moraine is but 770 feet, while at Laporte it is about 810 feet. At Stillwell, 7 miles southeast of Laporte, in a course directly away from the moraine, the altitude is only 730 feet, while at Wellsboro, directly south of Laporte and only 3 or 4 miles from the moraine, the altitude is 760 feet. Passing southwestward from Wellsboro, parallel with the outer border of the moraine, the altitude decreases to 730 feet at Wanatah.

The moraine is bordered by a gravel plain no farther west than eastern Porter County. In western Porter County the moraine extends down to

the border of the Kankakee marsh and borders this marsh somewhat closely across Lake County, Indiana. Whatever outwash there may have been along the border of the moraine in western Porter and in Lake County, has been removed by currents of water passing down the Kankakee.

Numerous references have been made to the gravel outwash on the east border of the Valparaiso morainic system in southwestern Michigan, and the relation of this outwash to the Valparaiso morainic system has been set forth in the discussion of the border between the Lake Michigan and Saginaw lobes. The line of escape for the small bodies of water in which this outwash was formed have been only partially worked out. It seems highly probable that the escape was southward into the Kankakee from the Dowagiac Valley, and possibly this line was open for waters collected in the headwater portion of the Pawpaw drainage basin. Drainage may have been greatly obstructed at times by the Saginaw lobe, and the height to which water rose was probably greatly influenced by the oscillations of the ice margin. The great amount of sandy and gravelly material formed along the elevated eastern border of the Valparaiso morainic system apparently indicates the action of water at heights of 300 feet or more above the level of Lake Michigan, or about 900 feet above tide. If this height were attained by the waters held between the Saginaw and Lake Michigan ice lobes in Allegan and Van Buren counties, they might easily find escape southward to the Kankakee Basin whenever the ice lobes afforded an opportunity for escape, for the head of the Kankakee Basin stands only a little more than 700 feet above tide. There does not appear to have been a uniform filling along the line of the supposed southward discharge. On the contrary the gravel plains appear to be rather in the form of small deltas extending out for a few miles where the slopes favored drainage, but absent along the portion of the morainic border where the slopes are unfavorable to such drainage. The gravel outwash appears to be nearly constant along the Dowagiac Valley throughout its entire length, a feature which seems to favor strongly the view that southward discharge was seldom interrupted, but on the Pawpaw and Kalamazoo tributaries, as already noted, the outwash is more restricted.

Upon the whole the Valparaiso morainic system displays a coarser outwash and gives evidence of more vigorous drainage than has been found on any of the morainic systems of the early Wisconsin series, though it is closely rivaled by the drainage from the Bloomington system.

SECTION V. THE LAKE-BORDER MORAINIC SYSTEM.

Between the Valparaiso morainic system and the shore of Lake Michigan there is a series of till ridges running nearly parallel with the lake shore. In the Illinois portion three ridges are developed in Lake and northern Cook County, but in Lake County, Indiana, at the head of the lake, these ridges are wanting. On the southeast border of the lake two of them reappear and a third one sets in north of the mouth of the Kalamazoo River. Though usually distinct, the ridges are in places coalesced, as described below. The gap at the head of the lake is so wide that strict correlation between each ridge on opposite sides of the gap can scarcely be made, but there is little room for questioning the interpretation that the ridges on the southeast border belong to the same morainic system as those on the west side of the lake. They not only have the same position with reference to the Valparaiso morainic system, but also are strikingly similar in topography and structure. It is found convenient to take up the discussion of the ridges of each district separately. Those west of the lake, in Lake and Cook counties, Illinois, are first discussed, and then those on the southeast border.

TILL RIDGES OF LAKE AND COOK COUNTIES, ILLINOIS.

THE OUTER OR WEST RIDGE.

The outer or west ridge enters Illinois from Wisconsin on the west side of the Des Plaines River, its outer border being for a few miles followed by Mill Creek, while its inner extends to the west bluff of the Des Plaines River. Just below Gurnee the river passes through a gap in the ridge, and for several miles south follows closely the outer border. The river then bears away a short distance, and the outer border of the ridge for the remainder of its course lies a mile or more east of the stream. In Lake County the ridge is sufficiently prominent and bulky to constitute a marked feature, and has a general width of about 2 miles. In the south part of the county it sends out a weak spur to join the middle ridge near Deerfield, while the main ridge continues south into Cook County, gradually decreasing in strength and dying out in a plain near Mont Clare, in the southwestern part of Jefferson Township (T. 40, R. 12 E.). For 5 or 6 miles north from its southern terminus it rises scarcely 10 feet above the bordering

plains, and is distinguishable from them mainly in being more undulatory. Where well developed, as in northern Lake County, the moraine has numerous knolls, 20 to 25 feet in height, and these stand upon a basement ridge whose relief is nearly 25 feet. A noticeable feature of this and also of the other ridges of this system is the difference in the breadth of the outer and inner slopes, the usual breadth of the outer slope being scarcely one-half that of the inner.

THE MIDDLE RIDGE.

As already noted, this ridge is joined to a spur from the west ridge south from Deerfield. The combined belt finds its southern terminus near the head of the Chicago River and at the border of the Glacial Lake Chicago. A possible continuation southward is discussed below. The course of the belt is south to north, through Northfield Township, Cook County. Upon entering Lake County it becomes distinct from the spur and remains a distinct ridge for a distance of 15 miles. It there, in sec. 18, Waukegan Township (T. 46, R. 12 E.), becomes united with the east ridge and remains united with it as far north as it has been examined. On each side of this ridge there is a narrow sag or slough. The sag on the east is marshy its entire length from Winnetka, in Cook County, northward to the latitude of Waukegan, a distance of nearly 20 miles. For a couple of miles at its southern end it has a width of one-half mile or more, but the usual width is only one-fourth mile. The sag on the western or outer border contains a marsh from Rondout Station southward to the Lake and Cook County line, a distance of about 9 miles.

This ridge, like the west ridge, has low knolls along its crest, 8 to 15 feet in height, but the coalesced ridge in northern Cook County is more billowy and carries knolls 20 feet or more in height. There are basins and winding sloughs among the knolls, which add to the morainic expression.

THE EAST RIDGE.

The southern terminus of the east ridge is at Winnetka, where Lake Michigan cuts it off. It has apparently had its entire east slope and a portion of the crest removed by the lake, there being a descent immediately from the bluff on the lake to the slough, which lies west of the ridge. Following the ridge north to Highland Park the crest and east slope appear.

Continuing north to Lake Forest, a narrow till plain appears on the east of the ridge, the inner border of the ridge lying back a half mile or more from the lake front. Still farther north, at Waukegan, the inner border lies back about 2 miles from the lake front. The usual width of this ridge is about 1 mile. The crest of the ridge usually stands 110 to 125 feet above the lake. At Winnetka, the higher portion being removed, it rises but 80 feet above the lake. The till plain east of the ridge stands 75 feet or more above the lake.

In this connection it may be remarked that the rate at which the lake bluff is being encroached upon by wave action has become a matter of much concern to the residents. It is estimated by early settlers that from Waukegan to Evanston there has been, during the thirty years from 1860 to 1890, a strip about 150 feet in width undermined and carried into the lake. This amounts to about 500 acres, representing, at present valuation, nearly $1,000,000 worth of property.

PROBABLE CONTINUATIONS.

None of these ridges have been found to have connection at their southern end with the massive Valparaiso morainic system, nor do they admit of continuous tracing around the southern end of the lake within (north of) that moraine. The weak development in that district seems the more remarkable since there is on the east side of Lake Michigan, northward from Porter County, Indiana, a series of ridges of similar size and complexity to that under discussion and which are probably its continuation. The conditions which affected the southern end of the ice lobe at the time these belts were forming are so poorly known that it may be difficult to ascertain what caused this wide gap. The question naturally arises whether the expanded lake and its old outlet may not have removed the ridges.

In the case of the western ridge this suggestion seems inapplicable, since the terminus at Mont Clare is outside the well-defined beaches and above their level. The ice sheet here, however, may have terminated in water held between its front and the inner slope of the Valparaiso morainic system in the brief period required for the cutting down of the outlet to the level of the upper beach. But in that case, while wave action may have removed weak morainic features, it seems scarcely probable that there could

have been a complete obliteration of so strong a belt as is present in districts to the north. In the case of Middle and East ridges, as shown below, there may have been some erosion by the lake outlet and lake waves.

Middle Ridge has its southern terminus as a well-defined ridge at the point where it meets the upper or Glenwood beach of Lake Chicago There is, however, near the southwestern limit of the city of Chicago, a till ridge known as "Blue Island," and connected with it a bowlder belt, each of which may be correlatives of this morainic ridge. This ridge leads north to south for a distance of about 6 miles along the line of Calumet and Worth townships, and Blue Island village is situated at its southern end. At that end the ridge stands about 60 feet above Lake Michigan, but rises northward to an altitude 85 or 90 feet above the lake. Its width, including the slopes, is only about 1 mile. The northern portion is gently undulating and is strewn with bowlders, but the remainder of the ridge is smooth and comparatively free from surface bowlders. Around this ridge there are shore marks in the form of eroded banks and gravelly beaches at an altitude 55 to 60 feet above the present lake level. On its west border sand from the old lake shore is drifted into dunes that extend nearly to the top of the ridge. Blue Island Ridge owes its elevation to a thickening of the drift deposits and not to a rock nucleus, for the rock surface is as low beneath it as on border plains. A well at Morgan Park, near the crest, reaches a level 70 feet below the base of the ridge before entering limestone.

A train of bowlders is traceable north from the north end of "Blue Island" through the western part of the city of Chicago to the vicinity of the Chicago River in Jefferson Township. Although portions of the line fall within a part of the city where dwellings are numerous, the bowlders still remain in sufficient numbers to be a noticeable feature. In the thinly settled part of the city from South Lynne southward to Blue Island they remain in about their natural abundance. The belt occupied by the bowlders is a mile or more in width. There appear to have been several hundred surface bowlders to the square mile along this line, while on bordering districts there are estimated to have been scarcely 100 to the square mile. From the north end of this bowldery tract to the south end of Middle Ridge the interval is but a few miles, and is mainly covered by deposits of lake sand and gravel which would obscure any bowlder connection

which may have existed. There seems, therefore, nothing to oppose the correlation of the bowlder train and Blue Island Ridge with Middle Ridge.

From the south end of Blue Island Ridge to the till ridges in Porter County, Indiana, no line of bowlders or indication of the position of the ice margin has been found. Such features as bowlders may, however, be concealed in much of that district by the heavy deposits of lake sand.

East Ridge apparently had some continuation southward beneath the present lake. Prof. L. E. Cooley, of the Chicago Drainage Commission, states[1] that in a series of dredgings in the south end of the lake, made a few years since, under his direction, a bowldery belt was traced for several miles southeastward from Winnetka, the present terminus of East Ridge. This bowldery belt is probably a residue from a ridge of till which has been cut away by the lake.

RELIEF.

West Ridge rises with a somewhat abrupt slope about 25 feet above the plain along the Des Plaines River. On the inner (eastern) side there is a gradual descent of about 40 feet to the plain along the Chicago River, and of 20 to 25 feet to the marshy plain in Lake County.

Middle Ridge has a relief of 20 to 25 feet above the marshy plain on its outer border, and a gradual slope of 25 to 40 feet to the sag or slough, which lies on its inner border.

East Ridge has a relief of 20 feet in northern Lake County and 35 to 40 feet in southern Lake and northern Cook counties above the sag on its outer border. The reliefs of all these ridges are lessened at the northern end because of increase of elevation in the sags or plains which separate them. The ridges each maintain a nearly uniform height of about 100 feet above Lake Michigan throughout their course in Illinois.

THICKNESS OF DRIFT.

In numerous borings, 75 to 100 feet in depth, no rock is struck and no outcrops of rock occur along this portion of the lake shore. The drift beneath the level of the base of these moraines was probably deposited by earlier ice advances. The following list of borings which have struck rock indicates that in several places at least the rock surface lies much below the surface of Lake Michigan.

[1] Communication to the writer.

At Senator C. B. Farwell's artesian well, in Lake Forest, rock is struck at 160 feet. The well mouth is 40 to 45 feet below the crest of East Ridge at Lake Forest and about 75 feet above Lake Michigan.

At Highland Park rock is struck at 160 to 175 feet. The elevation above the lake is 100 to 115 feet.

At Lloyd's artesian well, in the north part of Winnetka, rock is struck at 150 feet. The well mouth is by surveyors' level 78 feet above Lake Michigan.

At Ravenna a well strikes rock at 164 feet. The surface level has not been accurately determined, but it is probably about 100 feet above Lake Michigan.

Near Schermerville rock is struck at 147 feet. The surface elevation does not exceed 100 feet above Lake Michigan.

On the crest of West Ridge, in sec. 14, Maine Township (T. 41, R. 12 E.), rock is struck at 110 feet. The elevation is probably about the same amount above the lake.

STRUCTURE OF THE DRIFT.

Along the lake shore the bluffs from Winnetka to the vicinity of Waukegan rise abruptly 75 to 90 feet and present many good exposures of the drift to this depth. There is at the surface a pebbly yellow clay 8 to 13 feet in depth, which is similar to that in the other moraines. Beneath this clay is a grayish blue till containing occasional sand pockets saturated with water. These, however, form but a small part of the drift. The bulk of the bluff is a compact till, but moderately pebbly and exposing only an occasional embedded bowlder. It was noted that the pebbles and bowlders are usually striated.

Neither East Ridge nor West Ridge nor the northern portion of Middle Ridge has gravelly knolls of any consequence, but the southern portion of Middle Ridge, lying in Cook County, has many such knolls. Indeed, nearly every prominent knoll contains gravel. It seldom exceeds 15 feet in depth and appears to be confined to the knolls, for they are situated on a basement ridge of till similar to the till exposed along the lake bluff.

But one complete reliable section of the drift could be obtained, which, though valuable, needs to be supplemented by other records to furnish a

satisfactory knowledge of the lower portion of the drift. The well is located at Ravinia. Its section was furnished by the driller, William McWendle, of Oak Glen.

Section at Ravinia, Lake County, Illinois.

	Feet.
1. Pebbly yellow clay	11
2. Grayish-blue pebbly clay	60
3. Gray clay, very pebbly	10-12
4. Grayish-blue pebbly clay, lighter color than No. 2	70
5. Clay, resembling putty	4-5
6. Limestone	22
Total drift	164

TILL RIDGES ON THE SOUTHEAST BORDER OF LAKE MICHIGAN.

THE OUTER RIDGE.

The outer ridge is distinctly traceable only from the vicinity of Benton Harbor, Michigan, to Wheeler, in Porter County, Indiana. It is closely associated with the Valparaiso morainic system for a few miles north from Benton Harbor, but a ridge supposed to be its continuation is found west of the "Pine Plains" in Geneva Township, Van Buren County, and Casco Township, Allegan County. Farther north it has not been recognized and may be combined with Covert Ridge. It is separated usually from the inner border of the Valparaiso system by a narrow plain averaging scarcely more than 2 miles in width and nowhere exceeding 5 miles.

From the point of connection with the Valparaiso system, east of Benton Harbor, in Berrien County, Michigan, southwestward to the St. Joseph River, a distance of 4 or 5 miles, there is only a vaguely defined morainic belt. But immediately south of St. Joseph River, about 3 miles south of Benton Harbor, a definite ridge sets in, which leads southward along the east side of the Vandalia Railway to within a mile of Baroda. A gap about a mile in width here occurs, through which Hickory Creek finds a passage and which is also utilized by the railway. The ridge sets in on the west side of the creek, in sec. 10, T. 6 S., R. 19 W., and leads in a slightly winding course west of south to New Troy. At this village a narrow gap occurs, through which the North Galien River has a passage. From the south bluff of this stream the ridge leads southwestward past Three Oaks and comes to South Galien River about a mile north of the

State line. But here there is a very narrow gap and the ridge continues in a southwestward course across northwestern Laporte County, Indiana. The ridge is very weak for a mile or more about 5 miles southwest from where it crosses the State line, and there is a narrow gap at Trail Creek. From Trail Creek westward to the vicinity of Furness, in Porter County, a distance of about 12 miles, the ridge is double and the members are separated by a marsh a mile or less in width. From Furness westward to Bailey the ridge presents but a single crest. Near Bailey a belt of prominent dunes which border the shore of Lake Michigan spreads out to the south in such a way as to make it difficult to trace the low till ridge. It seems probable, however, that the till ridge continues but little beyond Bailey, for no evidence of its presence could be found in railway cuttings, which are quite numerous in the midst of the belt of dunes.

A possible continuation of this ridge is found toward the south in a narrow till ridge which leads southward from a point near Chrisman to the Valparaiso morainic system at Wheeler. This would involve an abrupt southward turn in the ice margin and bring it to the inner border of the Valparaiso morainic system.

In Lake County, Indiana, no sharply outlined till ridge has been found, but a low ridge with undulatory surface leads westward from Deep River at Hobart along the north side of Turkey Creek, a distance of about 5 miles. It is separated from the inner border of the Valparaiso morainic system only by a narrow plain, scarcely a mile in average width. Possibly this marks the continuation of the ridge under discussion. The system of ridges is as obscure in western Porter and Lake counties, Indiana, as in southern Cook County, Illinois. It, therefore, is no easy matter to decide upon the position of the ice margin in these counties at the time the outer ridge was in process of formation in counties to the east.

This till ridge governs drainage to a marked degree. In the Indiana portion South Galien River, East and West Trail creeks, and Calumet River all have their courses toward Lake Michigan checked and courses parallel with the lake produced by its presence. In Michigan the north flowing portion of North Galien River is, for several miles, parallel to the outer border of the ridge. The relief of the ridge scarcely reaches 50 feet where sharpest, and is usually but 20 or 30 feet. The plain outside rises from the border of the ridge toward the Valparaiso moraine, thus leaving along the outer

border of the ridge under discussion a valley-like depression which forms a natural line for drainage between the gaps through which the streams pass

The width of this ridge averages scarcely 1 mile and in places is but one-half mile. It has usually an abrupt outer border and a more gradual slope on the inner border. This feature is maintained where the ridge has a double crest, as well as where it is single.

Although the ridge usually presents a well-defined crest, it is seldom sharply morainic. Indeed, the surface is nearly as smooth as on portions of the bordering plains. The highest knolls scarcely exceed 15 feet, and the majority are but 5 to 10 feet in height. For a few miles near the State line the crest is sharp. It is also sharp in Porter County, Indiana, west from Furness. Usually it is nearly as smooth as the slopes.

COVERT RIDGE.

Covert Ridge receives its name from the village of Covert, in western Van Buren County, Michigan, which stands on its crest. It lies between the ridge just discussed and the shore of Lake Michigan, and is usually but 1 to 4 miles back from the shore of the lake. In places it comes to the lake and has been partially eroded by the lake waves, as indicated below.

Covert Ridge connects at the north with the Valparaiso morainic system, its point of connection being in Overisel Township, in northern Allegan County. It has, however, been traced a few miles farther north, along the inner border of the Valparaiso system, in Zeeland and Jamestown townships, Ottawa County, where its topography and structure distinguish it from the bordering Valparaiso moraine. No attempt has been made to trace it farther north. From Overisel Township it leads southwestward through the village of East Saugatuck to the Kalamazoo River, at New Richmond. The river makes only a narrow break scarcely more than a half mile in width, and the ridge continues southwestward coming to the shore of Lake Michigan, near the line of Ganges and Casco townships, Allegan County, exactly opposite the State line of Wisconsin and Illinois. In the middle part of the west boundary of Casco Township the lake has cut away nearly all of the ridge, leaving only a strip about one-fourth mile wide, belonging to its east slope. From this point the ridge bears nearly due south while the lake border bears west of south, and at South Haven its inner border is nearly a mile east of the lake. It continues south nearly

to Covert and reaches a distance of 4 miles from the lake just north of that village. Its course then changes to southwest and the ridge comes to the lake border near the middle of the west line of Hagar Township, Berrien County (T. 3 S., R. 18 W.). From this point it follows the bluff of the lake closely to the mouth of the St. Joseph River, where it is interrupted for about a mile. It sets in, however, in the city of St. Joseph and follows the shore of the lake southward for about 8 miles to the vicinity of Stevensville. It here bears inland, passing east of Bridgman and Sawyer, but returns to the lake shore again at Union Pier, and is nearly removed by the lake just below that point. The Galien River Valley interrupts the ridge for a space of about a mile, but the ridge reappears on its south bluff in sec. 36, T. 7 S., R. 21 W., and from this point is continuously developed as far south as the State line. About a mile south of the State line it becomes vague and is represented only by occasional slight ridging. It is traceable, however, as far southwest as the valley of Trail Creek in sec. 26, T. 38, R. 4 W., about 4 miles east of Michigan City, Indiana. Possibly it finds its continuation westward in the inner member of the double ridge which leads from Trail Creek Valley to Furness, Porter County, Indiana, though it seems quite as probable that it had its continuation nearer the lake shore, and has been either removed by lake waves or concealed by the dunes, there being beach lines closely associated with its western end in the vicinity of the valley of Trail Creek.

Throughout its entire length of about 80 miles this ridge maintains a nearly uniform width of about 1 mile, the only notable exception being a strip a few miles in length in western Allegan County, where it reaches a width of 2 or 3 miles. Like the outer ridge it presents usually a more abrupt slope on its eastern or outer border than on its inner border.

The surface of this ridge, like the outer ridge, carries only gentle swells and shallow saucer-like depressions except at the north where it assumes a sharper morainic expression. The change in expression sets in abruptly in northeastern Ganges Township, Allegan County, in the vicinity of Hutchinson Lake. From this point northeastward knolls 15 or 20 feet in height are common and occasionally knolls reach a height of 40 feet. There are also deep basins, the most conspicuous of which is the one occupied by Hutchinson Lake, which has an area of nearly a square mile and is bordered by knolls and ridges rising 40 or 50 feet above its surface.

From East Saugatuck northeastward the surface is billowy without well-defined basins, and this topography is maintained for some distance beyond the point of connection with the Valparaiso morainic system, as far as the examinations have been carried.

This ridge, like the outer ridge, has had considerable influence on the course of drainage. The north branch of Black River follows nearly its outer border from Hutchinson Lake southward to the vicinity of South Haven, while the south branch follows nearly the outer border from Covert northward to the same point, and the united streams there pass westward through a gap in the ridge to the lake. Pawpaw River follows the outer border of the ridge for about 8 miles in its lower course. Hickory Creek flows northward along its outer border for about 6 miles before entering the St. Joseph River. North Galien River follows the outer border for about 8 miles below the village of New Troy, where it is joined by South Galien, and the united stream passes westward through a gap in the ridge.

ZEELAND RIDGE.

During the summer of 1897 the writer discovered a till ridge in northwestern Allegan and southern Ottawa counties, Michigan, which lies west of Covert Ridge and which extends no farther south than the vicinity of the mouth of the Kalamazoo River, its further continuation having been cut away by Lake Michigan. This ridge is well developed immediately northeast of the village of Zeeland and it seems appropriate to apply to it the name Zeeland. The portion south of Holland, however, has been known by the residents as "May Hill." The writer has examined it only from the meridian of Holland northeastward to Grand River, north of Hudsonville, Ottawa County, a distance of about 20 miles.

The ridge stands 100 to 120 feet above Lake Michigan, where best developed, and has a width of scarcely 1 mile. It is interrupted by occasional gaps, the most notable being the one through which Black River passes, south of Zeeland, which is about 1½ miles in width.[1] From a point north of Vriesland northeastward to Grand River it lies along the west border of a large abandoned valley, and appears to have been partially

[1] This Black River should be distinguished from a stream of the same name entering Lake Michigan at South Haven.

removed by the stream which formed the valley. The same stream also passed through the gap south of Zeeland and perhaps has widened that gap.

This ridge, like Covert Ridge, is composed of a clayey till strikingly in contrast with the more porous till of the Valparaiso system. It is commonly spoken of as a "clay ridge," and it forms the southeast border of an extensive sand-covered plain, with which it is in sharp contrast.

The ridge carries only gentle swells 5 to 15 feet in height, but its relief above the lower tracts on either side is sufficient to make it a prominent feature. It rises about 30 feet above the general level of the sand-covered districts which border it on the west and about an equal amount above a narrow plain on the east which separates it from Covert Ridge.

The extent of this ridge toward the north remains to be determined, as no investigation has been made north of Grand River. An inspection of railway profiles suggests that its course may be directly north, past Coopersville into the southeast part of Muskegon County. The relation of this ridge to certain sand deposits found on its eastern border is discussed on a later page.

RELIEF.

The outer ridge and Covert Ridge each show slight relief above the districts on their outer border. The greatest relief scarcely exceeds 50 feet and the usual relief is but 25 or 30 feet. The abruptness of the outer slope, however, in each of the ridges renders this slight relief a somewhat conspicuous feature, and the ridges may be seen distinctly for a distance of several miles when viewed from their outer border. On the inner border the descent is gradual from the crest of each ridge, usually amounting to but 20 or 30 feet per mile.

RANGE IN ALTITUDE.

Each of the ridges show comparatively slight range in altitude. The lowest parts are nearly 75 feet above Lake Michigan and the highest scarcely 150 feet. Throughout much of its course each ridge stands about 100 feet above the lake. The crests of the ridges are usually but 40 or 50 feet above the level of the highest beach of Lake Chicago, and in places they come down nearly to the level of the beach. The plains bordering the ridges were quite extensively submerged by the lake or stood so little above the lake level as to be poorly drained until the lake level had been lowered.

THICKNESS OF DRIFT.

These ridges occupy a region in which the drift deposits are very thick, but it is probable that the drift deposited at the time of their formation is mainly confined to the ridges, with only a thin sheet on the plain which separates them and the plain between the Covert Ridge and the lake. The relief of the ridges probably represents approximately the thickness of the drift deposited at this stage. The following list of borings which have struck rock indicate that throughout much of this district the rock surface lies considerably below the surface of Lake Michigan:

At Hammond, in Lake County, Indiana, the distillery well penetrated 110 feet of drift, reaching a level 95 feet below the surface of Lake Michigan before entering rock.

At Owen's brick yards, in Hobart, Indiana, rock was entered at 150 feet, at a level 100 feet below the surface of Lake Michigan.

The Blair artesian well, in the northeast part of Porter County, entered rock at 240 feet, at a level 220 feet below the surface of Lake Michigan.

At the northern Indiana penitentiary, near Michigan City, Indiana, rock was entered at 172 feet, at a level 156 feet below Lake Michigan. A gas boring in Michigan City reached a level 230 feet below the lake before entering rock.

At New Buffalo, Michigan, a boring penetrated 212 feet of drift, entering rock at 192 feet below the level of Lake Michigan.[1]

At New Troy, Michigan, a well is reported to have struck rock at only 65 feet, or at a level but 20 feet below Lake Michigan. A well near New Troy, in sec. 30, T. 7 S., R. 19 W., is reported to have entered shale at a depth of 90 feet and a level about 20 feet below the lake.

At Sawyer Station, Michigan, Mr. Rough sunk a well which entered rock at a depth of 123 feet and a level 56 feet below Lake Michigan.

At Bridgman, Michigan, a well at the box factory entered rock at 140 feet, at a level 78 feet below Lake Michigan.

At the basket factory in St. Joseph, Michigan, rock is entered at about 123 feet below Lake Michigan and at a similar level in a well at the Park Hotel. The gas well at Benton Harbor entered rock at 124 feet below the level of the lake.

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[1] Geol. of Indiana, 1873, p. 431.

At South Haven, Michigan, a well at the basket factory entered rock at 105 feet below lake level. A well on the farm of J. Irving Pearce, a few miles southeast of South Haven (in sec. 31, T. 1 S., R. 16 W.), entered rock at 130 feet below lake level. A well on the farm of W. F. Conner, in sec. 34, T. 2 S., R. 17 W., reached a depth of 220 feet and a level 125 feet below Lake Michigan without entering rock.

A well in the southeast part of T. 1 N., R. 17 W., 157 feet in depth, reached a level nearly 100 feet below Lake Michigan without entering rock. Another well in sec. 29, T. 1 N., R. 16 W., 140 feet in depth, reached a level fully 100 feet below the lake without entering rock.

At D. Kitchen's, in sec. 16, T. 2 N., R. 16 W., a well reached a depth of 275 feet and a level 165 feet below Lake Michigan without entering rock.

A well 1½ miles southeast of Pier Cove, Michigan, 142 feet in depth, reached a level about 75 feet below the lake without entering rock.

STRUCTURE OF THE DRIFT.

At many points on each of these ridges there is a thin coating of sand. It is usually drifted into low knolls and ridges, and was apparently deposited in large part by wind. Where these sand deposits are 8 or 10 feet in depth wells along the ridges often pass into a blue till at the base of the sand, but where the sand deposits are thin or absent a yellow till several feet in depth occurs at the top of the blue till. In several sections, as shown below, the yellow till was found to have a thickness of but 3 or 4 feet. The usual thickness, however, is nearly twice that amount, and in places is not less than 20 feet. The ridge on the north side of the Calumet River, in Porter County, Indiana, furnishes several well sections in which the thickness of the yellow till is 15 or 20 feet. The body of the ridges seems to be composed of blue till having a large clayey constituent, and on the whole more compact than the blue till found in the Valparaiso morainic system. The till also is less stony as a rule than typical till. This till is occasionally replaced by sand or gravel, and it generally contains pockets and thin beds of sand and gravel of sufficient extent and at convenient depths to supply the shallow wells. There are places where a nearly pebbleless laminated clay replaces the till.

Bowlders are found in moderate number along each of the ridges. They consist largely of granite rocks, though there are many other classes of rocks present. As is usual in the moraines of this region, the surface

bowlders are composed very largely of pre-Cambrian crystalline rocks of Canadian derivation, rocks from the Paleozoic formations being comparatively rare. But the till contains a large number of local rocks, and its rock constituents vary from place to place, following in a general way the changes in the underlying rock formations. Large bowlders of sandstone were found on Covert Ridge in western Allegan County similar to those noted on the Valparaiso moraine in Allegan and Van Buren counties. A bowlder of red jaspery conglomerate, apparently from the Huronian outcrops north of Georgian Bay, was found on the Covert Ridge, a short distance northeast of East Saugatuck. The ice movement which formed the ridge can scarcely be supposed to have brought the bowlder from the parent ledge, for the line of axial movement was southward through the Lake Michigan Basin, and the radial movement was southeastward toward this ridge. The presence of this bowlder is probably to be accounted for through an earlier ice movement which crossed Michigan and the Lake Michigan Basin in a southwestward course, strewing bowlders along its path to be taken up by the later movements and redeposited in the later till sheets.

An excellent section of the structure of Covert Ridge is found on the shore of Lake Michigan a few miles north of New Buffalo, in sec. 25, T. 7 S., R. 21 W. The lake bluff here is about 95 feet in height. At the surface there is a coating of sand in places 6 or 8 feet in depth, but in other places only a few inches. Beneath it there is a brownish-yellow till which graduates into blue-gray till within 8 or 10 feet of the surface. For a depth of about 60 feet the till shows distinct lamination and has thin partings of sand and laminated clay. Below this depth it is somewhat harder and the lamination is very imperfect. It is probable that the lower 30 feet of the exposure is independent of the upper 60 feet. The latter alone appears to be referable to the stage of glaciation at which the ridges under discussion were formed. About one-half mile southwest from the point just described the lake bluff presents the following series:

Section of Covert Ridge, near New Buffalo, Michigan.

	Feet.
Beach gravels	8
Brown laminated clay, slightly pebbly, with thin partings of sand	1½
Blue laminated clay, slightly pebbly, with thin partings of sand	14
Coarse water-bearing sand	2
Blue-gray till, very stony, interbedded with thin layers of sand in horizontal beds, extending down beneath the level of the lake, exposed	30
Total	55½

It is probable that the upper 25 feet of this section is a deposit made in water, and possibly also the lower portion was deposited under similar conditions. As a talus obscures the lower portion of the bluff in places between these two sections, the exact equivalency of the beds at the base of the sections can not be established.

North of St. Joseph there are exposures along the shore of the lake in which large masses of cemented gravel and sand are interbedded with the blue till. This is apparently a local feature. The till here, as in the exposures near New Buffalo, shows traces of lamination and is scarcely so pebbly as typical till. An exposure west of Hagar Station, at a point where the lake bluff is cut back nearly to the crest of Covert Ridge, shows the following series of beds:

Section near Hagar, Berrien County, Michigan.

	Feet.
Sand, varying from a few inches to several feet	1–8
Yellow till, thickest where sand is thin	1–5
Blue till, not very stony	30
Sand, variable in coarseness, with thin clay beds	20
Blue-gray till, quite stony	50
Total	110

An exposure in sec. 18, T. 2 N., R. 17 W., shows a laminated clay at the base of the surface sand which may be referable to the glacial lake, though it seems more probable that it was deposited beneath the ice sheet. The section of the lake bluff is as follows:

Section of bluff of Lake Michigan in sec. 18, T. 2 N., R. 17 W.

	Feet.
Sand	4–8
Laminated gray clay, slightly pebbly	12
Sand and gravel	3
Blue-gray till, quite stony	15
Total	36

Several sections of wells were obtained in each of the counties traversed by these ridges, which throw light upon the structure of the drift to considerable depth. In a few cases the entire drift series has been penetrated. In presenting these well sections the discussion begins in Porter County, Indiana, and counties are taken up in succession toward the northeast.

A boring on the till ridge north of Wheeler, on the farm of Josephus Wolf, 157 feet in depth, has the following section:

Section of ridge north of Wheeler, Indiana.

	Feet.
Stony yellow till	15
Blue clay, slightly pebbly, with occasional thin sand beds	140
Gravel bed	2

Another boring on the same farm reached a depth of 200 feet without obtaining water or entering the rock. Usually wells in that vicinity must penetrate about 90 feet of compact clay before entering a water-bearing bed, but in a few places sand with water has been found at 30 feet or less.

Wells on the till ridge north of the Calumet River, in eastern Porter County, have reached a depth of 150 feet in a few cases without entering rock. One at Bailey, 148 feet in depth, has the following section:

Section of well at Bailey, Indiana.

	Feet.
Stony yellow till	18
Dry sand	40
Blue quicksand	40
Blue till	50
Total	148

A well immediately north of Chesterton, 97 feet in depth, has the following section:

Section of well near Chesterton, Indiana.

	Feet.
Stony yellow till	20
Soft blue clay, with few pebbles	50
Dry sand	15
Sand and gravel, with water	12
Total	97

On the same ridge, a mile farther east, the series is still more variable, as follows:

Section of ridge north of the Calumet River, near Chesterton.

	Feet.
Stony yellow till	20
Soft blue clay, with few pebbles	40
Dry sand	12
Hard blue till	5
Sand and gravel, with water	11
Total	88

Near the line of Porter and Laporte counties the wells penetrate only 3 to 5 feet of yellow till, beneath which is a soft blue clay, with few peb-

bles, which extends to a depth of about 50 feet, where water-bearing sand is entered.

At the Blair artesian well, in the northeast corner of Porter County, 240 feet of drift was penetrated if the surface sand be included. The well is located on low ground near the lake, only 15 or 20 feet above the lake level. The rock surface is, therefore, nearly 225 feet below the lake level. The following notes concerning the well were furnished by Mr. John Orr, of Michigan City:

Section of Blair artesian well in Porter County, Indiana.

	Feet.
1. Surface sand	18
2. Alternate layers of peaty blue clay and fine sand	12
3. Soft blue clay, slightly pebbly, with thin beds of gravel included	55
4. Water-bearing gravel bed	2
5. Fine sand	5
6. Water-bearing gravel	2
7. Blue clay harder than "No. 3," apparently a typical till	106
8. Water-bearing gravel	5
9. Blue clay alternating with beds of fine sand	35
10. Thin layer of shale	?
11. Gray limestone	180
12. Soft caving rock, probably shale	30
13. Limestone	6
14. Soft caving rock, probably shale	30
15. Hard limestone	370
16. Hard blue rock	2
Total depth	858

A flow of water began at a depth of 68 feet and was greatly increased at about 200 feet. At a depth of 370 feet the water became impregnated with sulphureted hydrogen and the flow was increased. The rate of flow is about 400 barrels per hour.

In Michigan City a prospect boring for natural gas obtained only a strong flow of water. The first flow was from the glacial drift at a depth of 210 feet. Water containing sulphureted hydrogen was struck at about 450 feet. The section (furnished by G. C. Marsh) differs somewhat from that at the Blair well, as follows:

Section of boring at Michigan City, Indiana.

	Feet.
Dry surface sand	15
Quicksand	10
Gravel	5
Blue clay, slightly pebbly	145
Very pebbly blue clay	22
Cobble, bowlders, and gravel	15
Gravel and sand with an occasional bowlder	40
Limestone and shale as in previous section.	

The following section of a well at the northern Indiana penitentiary, near Michigan City, appeared in an early report of the Indiana geological survey.[1] The well mouth is 16 feet above Lake Michigan and the water will rise 22 feet above the surface. The well has an estimated discharge of 300 gallons per minute:

Section of well at northern Indiana penitentiary.

	Feet.
Sand	48
Clay	4
Sand	24
Blue clay	66
Sand	30
Shale	76
Upper Silurian limestone	293½
Total	541½

The following section was observed in the bluff of Trail Creek near a mill in sec. 34, T. 38 N., R. 4 W.:

Section of bluff of Trail Creek.

	Feet.
1. Brown sand with thin beds of pebbles	6
2. Brown clay, nearly pebbleless, mainly noncalcareous, but with thin calcareous bands	3
3. Brown sand	1
4. Brown clay, similar to "No. 2"	1
5. Yellow sand	6
6. Laminated blue clay with few pebbles	10
Total	27

On the south border of Berrien County, Michigan, in sec. 19, T. 8 S., R. 20 W., two wells 85 feet in depth are mainly through a soft blue till containing but few pebbles. In that vicinity the blue till is often found within 4 feet of the surface. On the ridge at Three Oaks wells usually penetrate 6 or 8 feet of yellow till before entering the blue. Soft blue till extends to a depth of 70 feet, and there water-bearing sand is usually struck.

At New Buffalo, Michigan, the blue till is frequently exposed at depths of but 4 or 5 feet, and the wells in the higher part of the village usually penetrate about 50 feet of blue till before striking a water-bearing bed. On low ground near the shore of the lake flowing wells have been obtained at a depth of about 30 feet. The drift at New Buffalo, as reported in an early

[1] Geol. of Indiana, 1873, pp. 470–471.

volume of the Indiana Survey, has a depth of 212 feet at the Michigan Central Station, whose altitude is only 20 feet above the lake.[1]

At Sawyer a deep well made by Mr. Rough has the following section:

Section at Sawyer, Michigan.

	Feet.
Surface sand	3
Blue till, with sand bed at 25 feet and at bottom	120
Rock of bluish color, varying in hardness	208
Total depth	331

An exposure in the south bluff of Galien River, at New Troy, where the till ridge is undermined by the stream, shows a slightly pebbly blue clay from the river's edge up to a height of about 40 feet. Above this clay there is a brown till interbedded with calcareous sand, having a thickness of 12 feet. A well in the village of New Troy may have struck rock at a depth of 65 feet, though the owner of the well thinks that sand and gravel was entered below the supposed rock ledge. In case the latter interpretation is correct the former is probably erroneous.

At the point where the Galien River cuts through Covert Ridge, in sec. 2, T. 8 S., R. 20 W., there is sand at the top of the bluff 12 feet in depth, below which is a brown pebbly clay interbedded with sand which is quite calcareous. Both the till and the sand are in beds which are in arching and oblique attitudes. On the north bluff of the river nearly opposite this point a well 96 feet in depth entered blue till at 2 feet and continued in it to the bottom.

At Bridgman a boring 250 feet in depth entered rock at 140 feet, and struck an inflammable gas at about 160 feet which would burn a jet several feet in height. The rock is apparently a shale. The upper 80 feet of the drift is mainly blue till, but the lower 60 feet is gray sand, yielding water.

Along the St. Joseph River there are extensive exposures of blue-gray till in the west bluff from St. Joseph southward to the mouth of Hickory Creek, but in the east bluff exposures were found in which there is a blue silt free from pebbles rising to a height of 30 feet or more above the stream. This silt is usually capped with 15 or 20 feet of sandy gravel. A well near the east bluff, 2½ miles south of Benton Harbor, reached a depth of 153 feet without entering rock, and is mainly in blue clay; whether silt or till

[1] Op. cit., p. 431.

was not ascertained. East from here, in the vicinity of the mouth of Pipestone Creek, typical till is found in the east bluff of the river. A well on this bluff, in sec. 1, T. 6 S., R. 18 W., 138 feet in depth, does not reach rock. It penetrated about 30 feet of gravel, beneath which it was mainly in a blue till.

At St. Joseph a well at the Park Hotel, 165 feet in depth, enters rock only 4 feet and obtains a water that is slightly brackish. The upper 40 feet is mainly in blue till, but the remainder of the drift is largely a fine sand in which there are occasional beds of clay or silt carrying fragments of wood. Wood is especially abundant at about 140 feet. Rock was struck at the basket factory in St. Joseph at about the same level as in the hotel well, and a slightly brackish water was obtained.

An experimental gas boring at Benton Harbor, on low ground scarcely 15 feet above lake level, penetrated 135 feet of drift and sand. The upper 20 feet was entirely sand. Beneath this is a blue clay or silt, containing few pebbles, which graduates downward into a gray sand, also slightly pebbly, and this sand extends to the rock.

A well on the east border of Covert Ridge, in sec. 9, Watervliet Township, reached a depth of 125 feet without entering rock. It was through till with the exception of 5 feet of sand at the bottom. Another well in the same section entered blue till at 4 feet, which continued to the bottom of the well at 52 feet. Here a cemented gravelly crust was penetrated, beneath which water was obtained.

A boring on Covert Ridge, in sec. 34, Covert Township, at W. F. Conners, reached a depth of 220 feet without entering rock. It was mainly through blue till and no water was obtained; a dug well only 6 feet from it found water-bearing gravel at 36 to 38 feet.

Two wells just west of the village of Covert, in sec. 15, are 70 feet in depth. They penetrate 15 feet of yellow till, beneath which is a blue till extending to the water-bearing sand at the bottom of the wells. A well in the northeast corner of sec. 22, 80 feet in depth, is in till from top to bottom. A well on the west side of sec. 22, 97 feet in depth, penetrated 3 feet of surface sand, beneath which it was entirely in till to a water-bearing sand at bottom. A well in the north part of sec. 14, 100 feet in depth, passed through thin beds of sand which occur in the till at intervals of 15 or 20 feet. A well near the center of sec. 11 has a depth of 85 feet and is in till

from the top down to a quicksand at the bottom. A well in the SE. ¼ of sec. 2 has a depth of 70 feet and is in till with the exception of 4 feet of surface sand.

A well in the west part of sec. 25, South Haven Township, is in till from the top to a water-bearing sand at bottom. A well one-half mile southeast from South Haven, 125 feet in depth, is in till except 5 feet of water-bearing sand at bottom Several tubular wells in the village of South Haven have a depth of about 100 feet. After penetrating a few feet of surface sand they are in blue till nearly the whole depth. Some of the shallow wells in the village obtain water at the base of the surface sand. A boring at the basket factory in South Haven has the following section:

Section of boring at basket factory in South Haven, Michigan.

	Feet.
Surface sand	10
Soft blue clay, slightly pebbly, becoming harder toward bottom and containing bowlders in the lower 20 feet	130
Shale of dark color, varying in hardness	207
Total	347

On the plain east of Covert Ridge, in sec. 31, Geneva Township, a flowing well was obtained on the farm of J. Irving Pearce. Water rises 7 feet above the surface. The drift is mainly a blue till and has a depth of 190 feet. The well was continued 40 feet into the underlying shale.

A well on the plain east of Covert Ridge, in sec. 29, Casco Township, Allegan County, reached a depth of 140 feet without entering rock. After penetrating 25 feet of surface sand it passed through a thin bed of blue pebbly clay, beneath which it was entirely through fine sand.

On Covert Ridge, in sec. 25, T. 1 N., R. 17 W., a well 157 feet in depth penetrated 18 feet of surface sand, beneath which it was mainly through a blue-gray till. Another well in the same section penetrated 12 feet of surface sand, beneath which it was in a blue till to a depth of 146 feet. A well in the northeast corner of the same section penetrates scarcely any surface sand; there is instead a loamy yellow till 7 feet in depth, overlying the blue till. The latter is slightly pebbly and extends to a depth of 104 feet. There is then about 10 feet of stony material of reddish-brown color. This is underlain by blue clay, which extends to the water-bearing sand at 130 to 134 feet.

A well in sec. 6, on the inner slope of Covert Ridge, has the following section:

Section of well on Covert Ridge in sec. 6, T. 1 N., R. 17 W.

	Feet.
Surface sand	12
Blue clay, slightly pebbly	10
Fine white sand with a few pebbles	32
Cemented gravel alternating with beds of loose gravel	24
Total	78

In sec. 12, T. 1, R. 17, also on the inner slope of Covert Ridge, wells 30 to 50 feet in depth are mainly through sand, and the lake border from this point northward is heavily coated with sand.

On the outer slope of Covert Ridge, in northern Casco Township, till appears to have been deposited upon a thick bed of sand. The wells enter this sand at a depth of 10 to 25 feet, and those sunk to a depth of 35 or 40 feet do not reach the bottom.

On a swamp south of Covert Ridge, in southeastern Ganges Township, wells usually pass through a compact clay after leaving the surface muck, and find some difficulty in obtaining water in dry seasons. A well in sec. 36 reached a depth of 98 feet and found only a weak vein at about 40 feet.

A well on the crest of Covert Ridge, in sec. 16, Ganges Township, at an altitude about 100 feet above the lake, reached a depth of 275 feet without entering rock. Its section is as follows:

Section of well on Covert Ridge, in Ganges Township, Allegan County, Michigan.

	Feet.
Surface sand	6
Blue till	65
Blue quicksand	1½
Yellow sandy clay with pebbly layers	150
Blue till	20
Yellow sandy clay, changing to sand at bottom	30

A well in the northwest part of sec. 15, also on the crest of Covert Ridge, penetrated 30 feet of surface sand, beneath which was a blue till extending to the water-bearing sand at 86 feet.

A well on the crest of the ridge, near the line of secs. 3 and 4, at an altitude 105 feet above the lake, reached a depth of 190 feet without entering rock. There is 8 feet of yellow till at the surface, beneath which the well appears to have been entirely in a blue-gray till.

In the vicinity of Hutchinson's Lake the wells range in depth from 40 to 105 feet and are largely through sand or sandy gravel.

At Fennville wells in some cases penetrate 50 feet of sand, with which there are thin beds of peaty material associated. A hill east of this village, which stands about 50 feet above the level of the railway station, has till at the surface.

At Drenthe, on the inner slope of Covert Ridge, in southern Ottawa County, flowing wells have been obtained; one in a ravine at the sawmill has a head 8 feet above the surface and will flow 80 barrels per day from a 2-inch pipe. The water is obtained from sand below blue till at a depth of 92 feet. Another well a few rods west is siphoned into a trough in the same ravine. A well 1 mile north of Drenthe, 155 feet in depth, is mainly through blue till, except in the lower 15 feet, where water-bearing sand and gravel is found. Its head is sufficient to barely reach the surface. Many wells along the ridge east and south from Drenthe have been sunk to a depth of 100 feet or more, mainly through blue till. The till sheet extends westward from this ridge to the shore of Lake Michigan in northwestern Allegan County.

CHARACTER OF THE OUTWASH.

The Valparaiso morainic system formed a retaining wall for waters escaping from the ice sheet along the outer border of the ridges under discussion, except at the "Chicago Outlet," and possibly at the St. Joseph River Valley. It is probable therefore that the district between the ice margin and the Valparaiso morainic system was occupied either by lakes or by very sluggish streams, except perhaps for a few miles in Lake and northern Cook counties, Illinois. There are found indications of a moderate rate of flow, accompanied by gravelly outwash, along the Des Plaines Valley below the point where the outer ridge crosses the river near Gurnee. The force of the current was sufficient to carry the gravel as far down the valley as the vicinity of Des Plaines Village and form a belt a mile or more in average width. The gravel is only a few feet in depth.

Much of the low country bordering these ridges in southern Cook County, Illinois, and in northwestern Indiana and southwestern Michigan has been covered by the waters of Lake Chicago, and the deposits made by this lake can not easily be separated from any deposits of similar character which may have been formed as an outwash from the ice sheet. There are

places where wells encounter a more pebbly material at the base of the sand than near the surface, but it is not certain that these pebbles were an outwash from the ice sheet. Indeed, it seems quite probable that they may have been worked over and deposited by the waters of the lake.

ASSOCIATED TILL PLAINS.

The ridges just discussed occupy but a small portion of the area embraced between the Valparaiso morainic system and the shore of Lake Michigan. The greater part of the area is a plain, underlain by till deposits. The plane tracts, as is shown later, were largely covered by Lake Chicago and have received deposits of sand or gravel from the waters of that lake.

ALTITUDE AND SLOPES.

In the portion of the plain west and south from Chicago the altitude at the inner border of the Valparaiso morainic system is 40 to 50 feet above Lake Michigan. From this border there is a gradual descent toward the lake, and the till scarcely rises above lake level along the present shore within the limits of the city. At the time the upper or Glenwood beach was formed lake water covered the entire plain west and south of the city as far as the borders of the Valparaiso morainic system, the altitude of that beach being 55 to 60 feet above the present lake level.

Upon passing northward this till plain is divided into several narrow plains which separate the till ridges, and these plains soon rise above the level of the upper beach. The plain that lies between the west ridge and the Valparaiso moraine slopes eastward at the rate of several feet per mile. Its rise toward the north amounts to but 1½ to 3 feet per mile. At Ovington Station, on the Omaha Division of the Chicago and Northwestern Railway, the west border next the Valparaiso moraine is but 635 feet. It rises to about 690 feet at the line of Cook and Lake counties, a distance of 18 miles, and to about 725 feet in northern Lake County, a distance of 24 miles farther. The plain between West and Middle ridges rises from 630 feet at Oak Glen to 680 feet at Deerfield, a distance of 6 miles. From Deerfield north to the State line, a distance of 24 miles, it is shown by the Chicago, Milwaukee and St. Paul Railway profile to stand at 670 to 685

feet. Russell Station, situated on this plain near the State line, is 673 feet. The plain between Middle and East ridges rises from 630 feet, opposite Winnetka, to about 670 feet at the point where the ridges unite, 20 miles north from Winnetka.

In Indiana the border next the Valparaiso morainic system stands 50 to 70 feet above Lake Michigan, the lesser altitude being near the Illinois line and the greater near the Michigan line. The plain between the Valparaiso moraine and the outer till ridge is but 2 to 3 miles wide in Porter and Laporte counties; it however shows a descent toward Lake Michigan. There is also a perceptible descent from the till ridge toward the lake. In western Porter and in Lake counties the slope is apparently continuous toward the lake from the border of the Valparaiso morainic system, no well-defined till ridge being present. For a distance of 2 to 5 miles south from the lake the sand deposits capping the till are heavy and their base is about as low as the surface of Lake Michigan.

In Berrien County, Michigan, the plain between the Valparaiso morainic system and the outer till ridge stands 60 to 90 feet above Lake Michigan and has a slight descent toward the lake. As it is but 2 to 4 miles in width, the west border is only a few feet lower than the east. The plain between the outer ridge and Covert Ridge stands 50 to 75 feet above Lake Michigan, and also has a slight descent toward the lake. Its width in places is less than a mile and nowhere exceeds 3 miles.

In Van Buren and Allegan counties the lowland tract between the Valparaiso morainic system and Covert Ridge is less smooth than the southward continuation in Berrien County. There are occasional ridges and knolls of glacial drift ranging in height from 50 feet downward to 10 feet or less. There are also numerous sandy ridges and knolls with a height ranging from 30 feet downward to barely detectible waves in the surface. The presence of the sand has tended to make the surface more uniform in elevation, since it is deeper in depressions than on the higher points. The plane-surfaced part of the lowland stands usually 75 to 100 feet above Lake Michigan, while the knolls occasionally reach a height of 150 feet or more above the lake. This lowland tract presents greater oscillations in level in passing from north to south than from west to east. It is generally somewhat lower on the borders of the valleys than on the divides between them. If the

sand were removed the variations would be still greater, since the sand is thicker on the borders of the valleys than on the divides.

Covert Ridge follows the shore of Lake Michigan so closely that a plain is present on its inner border along only a small part of its course from the State line northward to the Kalamazoo River. Where present it shows a descent of 20 or 30 feet per mile toward the lake. In places where the ridge is distant 2 or 3 miles and its inner border stands 60 to 70 feet above the lake the till surface drops down nearly to lake level at the lake shore. Sand deposits have considerable depth on the lower parts of this plain and bring the surface up to a height of 35 to 40 feet or more above the lake.

THICKNESS OF DRIFT.

On the Illinois portion of these plains there is much difference in the thickness of the drift. The difference in thickness is due almost entirely to the variation in the surface of the underlying rock strata, since the surface of the plains has only a slight variation in altitude. Within the city of Chicago, where the surface is especially flat, several rocky prominences come to the surface, or are concealed but slightly by drift, while among them the drift accumulations extend to depths of 100 to 125 feet or more. Mr. Samuel G. Artingstall, formerly city engineer, has prepared a map of the city showing the distance to rock in many places. This indicates that a filled valley with rock floor 100 to 125 feet below lake level passed through the north central part of the city, entering the lake south of Lincoln Park. West from the city the rock rises over quite extensive areas nearly to the surface of the plain or to a height of 30 to 60 feet above the level of Lake Michigan.

In northern Cook and in Lake County, between the till ridges as well as beneath them, the rock surface has an average altitude somewhat lower than in the low plain in the vicinity of Chicago, for the majority of the wells reach a level about 50 feet below the surface of Lake Michigan before entering rock. It is estimated that the thickness of drift in this northern portion will average nearly 150 feet, while in the low plain the average will scarcely exceed 50 feet.

The thickness of drift in the Indiana and Michigan portions is usually great, as has been indicated above. (See pages 392–393.)

STRUCTURE OF THE DRIFT.

The drift beneath the Illinois portion of these till plains, like that of the ridges, consists largely of a soft blue till, beneath which are remnants of a hard till of earlier age. The tills appear to be of direct glacial deposition, even in portions of the plain which lie within the limits of the beaches. The clayey matrix of the soft till seems to be less thickly set with stones than that of the underlying hard till, but in both tills many of the stones are glaciated and show little evidence of water abrasion. The rocky constituents grade from bowlders several feet in diameter down to minute pebbles. These, in the upper or later till, are made up in large part from the local upper Silurian rocks, probably less than 10 per cent being from the pre-Cambrian Canadian rocks. Fragments of Devonian rocks, apparently from ledges outcropping to the north of Chicago, are sparingly represented.[1] The clayey matrix is highly calcareous, and under the microscope it is found that angular or but slightly rounded grains of limestone constitute a large proportion of the fine material. With the minute limestone fragments there appear quartz grains, bits of shale, and fragments from crystalline rocks of various kinds. Whether the rock constituents of the older till differ markedly from those of the newer has not been ascertained. Its situation immediately upon the Lockport (Niagara) limestone would, in all probability, result in the incorporation of an even larger proportion of fragments from this rock than appears in the upper till.

One of the most conspicuous instances of the occurrence of the lower till within this area is that brought to light in the excavation of the Chicago Drainage Canal. Immediately east from Summit the canal for about a mile extends a few feet into a very hard, partially cemented till, apparently of early glacial age. Its hardness compared with that of the overlying till is so marked that the contractors who engaged to excavate this part of the channel were obliged to abandon the steam shovel which had been used in the soft till and to resort to blasting. It is probable that this old drift fills depressions in the rock quite extensively in this district, but as no special attention has been given its identification the instances recognized are not

[1] On the microscopic structure of certain bowlder clays, and the organisms contained in them, by Dr. George M. Dawson: Bull. VI, Chicago Academy of Sciences.

numerous. The well drillers usually distinguish the hard till from the overlying softer till and apply to it the name "hardpan," while the soft till is called clay.

Although the great body of the drift is till, there are found numerous thin beds of sand or gravel in which water collects in sufficient quantities to supply the wells. There are also small pockets of dry sand or gravel occupying but a few cubic feet each. Such pockets were found in the excavation of the main lake tunnel, and have been described by Dr. Edmund Andrews in a paper published in the American Journal of Science.[1] They were in some cases completely inclosed by till.

On the surface of the plain both above and below the upper beach there is quite generally present in Lake and Cook counties a clay in which pebbles are far less numerous than in the till; it, however, carries occasional bowlders. It ranges in thickness from a few inches up to several feet. This deposit is perhaps a subaqueous till dropped in a body of water held between the ice front and the higher parts of the morainic system while the ice sheet was still overhanging the inner slope.

The depth of leaching and oxidation is markedly less on the plain covered by Lake Chicago than on the till ridges or the Valparaiso morainic system. Numerous acid tests show the leaching on the plain to extend only to a depth of a few inches, seldom more than 2 feet. On the till ridges the leaching is usually thorough to a depth of 3 or 4 feet, while on the Valparaiso system it is rare to obtain a response with acid within 5 or 6 feet of the surface. On the plain and also on the till ridges the surface oxidation is usually but 3 to 6 feet, while on the Valparaiso system it is 6 to 10 feet or more. This difference in the amount of oxidation and leaching may be attributable in part to the more compact nature of the till ridges and plains, but it is probably in part due to the later date at which they became exposed to atmospheric action.

There have been several deep lines of excavation made in Chicago and vicinity which have afforded excellent opportunities for studying the structure of the drift. The longest line is the Drainage Canal, now under construction, which opens a channel 25 to 40 feet in depth from the Chicago River at Bridgeport to the Des Plaines River at Summit. Along the Des

[1] Am. Jour. Sci., 2d series, vol. 43, 1867, pp. 75–77.

Plaines also the excavation is largely in drift to the vicinity of Lemont, where the canal becomes a rock channel. From Bridgeport to Summit there is little besides till, but from Summit to Lemont gravel, sand, and the coarser material deposited or left as a residue along the line of the old lake outlet form a large part of the section.

In the Fullerton avenue conduit, which leads eastward into the lake through the north part of Chicago, the drift is mainly till, but surface sand is a conspicuous deposit. From its western end to within 2,000 feet of the lake the rock surface is found at a depth of 43 to 54 feet. Within 100 feet east from this point it drops down to 80 feet, passes below the conduit, and does not appear farther east. The surface sand has its greatest thickness at about 1,700 feet from the lake, where it reaches 25 feet. It decreases westward to only 12 feet at a distance of 6,000 feet from the lake, and entirely disappears before reaching the Chicago River Valley. Toward the lake shore also it decreases, but holds a thickness of about 18 feet for 1,400 feet from the shore. At the water's edge the depth is but 10 feet. The profile continues out 1,100 feet beneath the lake, and there is but 3 feet of sand at its terminus.

Numerous borings and excavations in the south part of Chicago, in Hyde Park Township, show sand deposits ranging in depth from 5 feet or less up to about 20 feet. Till usually underlies the sand except where the rock comes near the surface. In this connection it may be remarked that the heavy deposits of sand in Cook County are found chiefly along the present lake border from Evanston southward, where there is a continuous belt of sand ranging in width from one-half mile to 3 or 4 miles and having an average depth of not less than 10 feet. Over much of the plain west of this sandy belt the deposition was so light as scarcely to conceal the surface bowlders and in places leaves only a trace of sand in the soil. The south-westward lake outlet appears to have carried away much of the sand which was brought into the southern end of the lake while that outlet was open.

In the portion of Indiana between the Valparaiso morainic system and Lake Michigan sand deposits are heavy as far south as Calumet River in Lake and western Porter counties and nearly as far as the inner border of the till ridge in northeastern Porter and northwestern Laporte counties, a

belt whose width varies from scarcely 2 miles up to fully 5 miles. Where the dunes are highest the sand probably has a thickness of about 200 feet, for the dunes attain a height of 150 to 175 feet, and the sand, as shown by wells, extends a few feet below the lake level. Throughout much of the belt the sand probably exceeds 25 feet in depth and may average twice that amount. South of Calumet River, from the mouth of Salt Creek, near Chrisman westward past Lake and Liverpool to Griffith, there is a belt of sand a mile or more in width which has generally a depth of about 20 feet. East from Salt Creek the depth is much less. The sand is also of slight depth west from Griffith except along the line of the beaches.

Beneath this heavy deposit of sand there appears to be but little oxidized clay, a feature which favors the interpretation that the clay was not long exposed to atmospheric action before the sand deposition occurred. The wells usually pass immediately into a blue clay. This clay, so far as can be learned from well drillers, is but slightly pebbly and apparently is in places free from pebbles. It seems to maintain this character to great depth, as is indicated by sections of wells already given. It differs markedly from the blue till of the neighboring portion of the plain in Cook County, Illinois, and appears also to be somewhat less pebbly than the blue clay of the neighboring district in southwestern Michigan. There are few exposures afforded by the streams in the district where sand is heavy, but exposures of slight depth are numerous outside the limits of the heavy sand. From these exposures it appears that the clay has generally but few pebbles, and several exposures have been found in which it is pebbleless.

The most extensive exposures of pebbleless clay noted are along Deep River, in the vicinity of Hobart, and it appears to be present over an area of several square miles between Deep River and Salt Creek. Prof. W. S. Blatchley, State geologist, reports a similar clay at Chesterton and Michigan City.[1] This pebbleless clay is oxidized to a depth of a few feet, beneath which it presents a blue color similar to that of the pebbly clay of neighboring districts. It is highly calcareous and carries numerous limestone nodules near the bottom of the oxidized portion. It seems even more calcareous than the pebbly blue clay. Professor Blatchley has published

[1] Communicated to the writer.

the following analyses of samples of these pebbleless clays, made by Prof. W. A. Noyes, of Terre Haute, Indiana.[1]

Analyses of clays of Pleistocene age.

	Hobart.	Garden City.	Chesterton.	Michigan City.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Silica	50.56	50.37	53.02	50.47
Titanium oxide	1.00	.65	1.30	1.45
Alumina	13.11	9.93	10.72	12.77
Combined water	2.76	1.50	2.21	3.14
Total clay base and sand	67.43	62.45	67.25	67.83
Ferric oxide	2.98	2.10	2.54	2.44
Ferrous oxide	2.32	2.05	2.22	2.52
Lime	7.87	10.26	8.38	8.17
Magnesia	5.06	6.26	5.28	5.22
Potash	3.74	3.04	3.25	3.70
Soda	.70	.79	.86	.73
Total fluxes	22.67	24.50	22.53	22.78
Carbon dioxide	9.62	12.50	10.48	9.80
Total	99.72	99.45	100.26	100.41

In explanation of the contrast in the amount of coarse material in the clays bordering the lake in northwestern Indiana, compared with those in Cook County, Illinois, it may be remarked that it is probable that the character of the underlying rocks will prove an important factor. In Cook County, Illinois, the underlying rocks are the somewhat resistant Lockport (Niagara) limestone, while in the neighboring portion of Indiana the rocks immediately beneath the drift are the Devonian shales, which are easily comminuted and ground into a clayey material. It is probable, however, that the conditions of deposition were slightly different in the two districts. In Cook County the southwestward line of discharge may have been open sufficiently to allow a considerable part of the fine material to be carried down the Des Plaines Valley, while in the Indiana district it may all have been deposited without much transportation or sifting out of the finer material. The localities where the pebbleless clay are best exposed are beneath the bay-like extensions of Lake Chicago, and may possibly be

[1] 22d Ann. Rept. Indiana Geol. Survey, 1898, pp. 128, 134, 137, and 139.

composed of sediment which settled in the waters of the bays. The great amount of calcareous material, however, seems to indicate that they are a glacial rather than lacustrine silt. The scarcity of evidence of life in the early stages of the lake seems to indicate that but little calcareous material can be looked for from that source.

SECTION VI. STRIÆ WITHIN LIMITS OF SHELBYVILLE MORAINE.

The table of striæ given below includes all exposures of which the writer has knowledge either through personal observations or from publications and correspondence. There are several observations taken by Messrs. J. T. Campbell, O. P. Jenkins, A. H. Purdue, and J. A. Udden, hitherto unpublished, which have been kindly contributed for publication in this report The bearings taken by the writer, except when so designated, are not corrected for magnetic variation. The bearings taken in western Indiana by Collett, Campbell, and Jenkins are corrected for magnetic variation, but so far as known all others are magnetic. The magnetic variation in western Indiana is only about 3° east and in western Illinois 6° east.[1]

Table of striæ within limits of Shelbyville moraine.

Location.	Bearing.	Observer.
Near Troutman, Ind	S. 8° E	Collett.
Coal Creek bluff, 3 miles west of Waynetown	S. 18° E	Collett.
Coal Creek bluff, 3 miles west of Waynetown *a*	S. 20° W	Hopkins.
Near Darlington, Ind	S. 31° E	Leverett.
Near Darlington, Ind. *b*	S. W	Thompson.
In northern Parke County, sec. 27, T. 17, R. 7 W	S. 39° 48′ E	Campbell.
In northern Parke County, sec. 27, T. 17, R. 7 W *c*	S. 34° 30′ E	Campbell.
Williamsport, Ind	S. 68° E	Leverett.
Williamsport, Ind. *d*	S. 8°–10° W	Salisbury.

a See Collett, Geol. of Indiana 1875, p. 370. Also Hopkins, Geol. of Indiana, 1895, p. 273. The observations by Mr. Hopkins indicate that the bearing reported by Mr. Collett should be S. 18° W.

b The striæ reported by Mr. Maurice Thompson were probably formed by the Erie lobe.

c Two exposures on the bluff of Sugar Creek, 100 feet apart, show a difference of 5° in bearing. The observer, Capt. J. T. Campbell, of Rockville, Indiana, has reported several exposures of glacial striæ in Parke and Putnam counties, Indiana, which bear southwestward, and accordingly are referred to the Maumee lobe. They are discussed in another report now in preparation.

d The observations reported by Professor Salisbury probably represent a movement connected with the Wisconsin stage of glaciation, while the observations reported by the writer belong apparently to an earlier glaciation. Two miles east of Williamsport, on the north side of the Wabash, Professor Chamberlin found a third set of striæ with westward bearing, which apparently pertain to the invasion of the Erie lobe. (See Seventh Annual Report U. S. Geol. Survey, p. 207.)

[1] See map of Henry Gannett, showing distribution of magnetic variation in the United States for the year 1900: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, Pl. II.

Table of striæ within limits of Shelbyville moraine—Continued.

Location.	Bearing.	Observer.
Near Fountain post-office, in sec. 4, T. 20, R. 8 W., main bearing.	S. 40° E	Siebenthal.
Near Fountain post-office, in sec. 4, T. 20, R. 8 W., scattering striæ.	S. 56°-62° E	Siebenthal.
Logansport, Ind., on bank of Eel River	S. 14° E. or N. 14° W.	Leverett.
East of Logansport, on bed of Eel River	S. 58° W	Leverett.
Monon, Ind	S. 34° E	Chamberlin.
Monon, Ind. *a*	S. 85° W	Chamberlin.
Rensselaer, Ind	S. 8°-14° W	Purdue.
Quarry, near Kentland	S. 7° E	Chamberlin.
Quarry, near Kentland *a*	S. 77° W	Chamberlin.
South bluff of Illinois River, near Lasalle	S. 75° W	Leverett.
Mazon Creek bluff, sec. 30, T. 33 N., R. 8 E	S. 44° W	Leverett.
Near Morris, Ill., in sec. 24, T. 34, R. 7 E	S. 50°-55° W	Leverett.
Near Morris, Ill., in sec. 19, T. 34, R. 8 E	S. 60° W	Leverett.
Near Morris, Ill., in sec. 18, T. 34, R. 8 E	S. 30°-38° W	Bradley.
Near Morris, Ill., in sec. 18, T. 34, R. 8 E	S. 40°-55 W	Leverett.
In Lisbon, Ill	S. 50° W	Leverett.
Aux Sable Creek, west of Minooka	S. W	Udden.
Aux Sable Creek, sec. 9, T. 35, R. 8 E	S. 47° 45′ W	Leverett.
Brodie's Quarry, on Fox River bluff, north of Millington, Ill.	S. 9° 30′ E. to S. 27° 30′ W.	Leverett.
Little Rock Creek, sec. 33, T. 37, R. 6 E	S. 31° W., S. 37° W., S. 40° W.	Leverett.
Sec. 34, T. 37, R. 6 E	S. 42° W	Leverett.
Sec. 1, T. 37, R. 6 E	S. 110° 30′ W	Leverett.
Joliet, near penitentiary	S. 96° W	Leverett.
Dupage River bluff, at crossing of Chicago, Rock Island and Pacific R. R.	S. 42° 30′ W	Udden.
Kankakee River bluff, in sec. 9, T. 33, R. 9 E	S. 58° W	Leverett.
Near Wilmington, Ill., in sec. 31, T. 33, R. 10 E	S. 43° W	Leverett.
Beckford's Quarry, sec. 10, T. 33, R. 11 E	S. 31° W	Leverett.
Lemont, near Des Plaines "Cut-off"	S. 60° W	Guthrie.
Between Willow Springs and Sag Bridge	S. 18° W	Leverett.
West of Summit	S. 34° W	Leverett.
North of Summit, near Santa Fe railway bridge	S. 86° W	Leverett.

a At Monon and near Kentland there are two systems of striæ reported by Professor Chamberlin. In the latter instance the southward pointing striæ lie in grooves and furrows in the limestone, while the westward pointing striæ only affect the crests of these furrows, which have been slightly truncated by the later westward movement. (See Seventh Annual Report U. S. Geol. Survey, p. 207.) The writer made an observation of striæ 2 miles east of Kentland, in which they appear at various angles between S. 4° E. and S. 75° W., in such manner as to suggest that more than two movements affected the rock ledge.

Table of striæ within limits of Shelbyville moraine—Continued.

Location.	Bearing.	Observer.
Lyons, in Des Plaines Valley	S. 40° W. to S. 67° W.	Leverett.
Lagrange	S. 54° W.	Leverett.
West of Elmhurst, at quarry	S. 67° W.	Leverett.
East of Elmhurst, in sec. 17, T. 39, R. 12 E.	S. 58° W.	Leverett.
Hawthorne quarries, west part of Chicago	S. 60°–64° W.	Leverett.
Quarry at Western and Chicago avenues, Chicago	S. 68° W.	Leverett.
Fullerton avenue conduit, Chicago	S. 60° W.	City engineer.
Quarry at Eighteenth and Robey streets, Chicago	S. 48°–55° W.	Leverett.
Stony Island, South Chicago	S. 30°–50° W.	Leverett.
Blue Island quarries, 2 miles southwest of village	S. 50° W.	Leverett.
Blue Island quarries, 2 miles southwest of village	E.–W.	Guthrie.
Thornton, in valley east of village [a]	S. 27° W.	Leverett.

[a] Mr. Ossian Guthrie reports having observed striæ at Thornton bearing more nearly westward. (See Guthrie's pamphlet on the Lake Michigan Glaciers, map 3.)

Considerable difficulty is experienced in assigning striæ in northwestern Indiana to the proper ice lobe. That district was invaded from the northward by the Illinois lobe and subsequently from the eastward by another portion of the ice sheet, the Saginaw-Erie lobe, which in the closing stages of glaciation became differentiated into the Saginaw lobe and the Erie or Maumee lobe. Accordingly both southward and westward bearing striæ are found. In some places, as at Monon and Kentland, a single rock surface presents both southward and westward bearing striæ, the westward being the later. Usually, however, the striæ formed by the earlier ice movement were either protected by drift deposits from the action of the later ice movement, or they were so exposed as to be effaced by the later movement.

There are striæ on the north bank of Eel River in the city of Logansport, concerning which the direction of movement is not certain. The bearing is N. 14° W. or S. 14° E. Immediately north of Logansport lies a heavy moraine formed on the north border of the Erie lobe, which, as just noted, extended westward from the Lake Erie Basin. We may suppose the striæ to have been formed by a northward movement toward this moraine, but it is quite as probable that they were formed by an earlier southward movement, independent of the moraine and perhaps referable to

the Illinois lobe. A careful examination of the striated surface failed to disclose decisive evidence whether the movement was northward or southward. It may be remarked in this connection that just above the city of Logansport the bed of Eel River shows heavy glacial grooves bearing S. 58° W., which are evidently the product of the movement from the Lake Erie Basin. It seems scarcely possible for the same ice movement to produce, within the limits of a single township, striæ with bearing differing 108 degrees, and that too in a comparatively smooth region. But so little is known as yet concerning the possibilities of ice movement, that judgment should perhaps be reserved.

The striæ of northeastern Illinois show some interesting deviations from a general southwestward course. In the Des Plaines Valley there is a range from S. 18° W. to S. 96° W. Three observations between Summit and Lemont show bearings S. 34° W., S. 18° W., and S. 60° W. The striæ bearing nearest westward are accompanied by heavy grooves which seem to call for the action of a thick ice sheet, but the other exposures show only faint striation, and it has occurred to the writer that possibly this faint striation is attributable to masses of ice floating down the valley after the ice sheet had withdrawn. Another locality in northeastern Illinois, where the striation is thought to be referable to floating ice, is on the bluff of Fox River, north of Millington, in Kendall County, where faint striæ occur with bearings ranging from S. 9° 30′ E. to S. 27° 30′ W. In a great majority of exposures in the Illinois district glaciation is heavy, with complete planing of surface and often with heavy grooves, and can scarcely be referred to floating ice.

At Joliet striæ were observed with bearing slightly north of west, but this bearing is almost at right angles with the trend of the Minooka till ridge a few miles west of Joliet, and is probably referable to the ice movement which produced that ridge. The same explanation probably should be given for the bearing 20° north of west, shown in an exposure a few miles west of Aurora (sec. 1, T. 37 N., R. 6 E.), for a moraine with NE.–SW. trend passes through the district immediately northwest of these striæ.

On Stony Island, in the south part of Chicago, the rock quarry where glaciation was observed has beds which dip toward the southeast with an angle of 30 degrees or more. Heavy scorings follow the line of strike, with

a bearing S. 44° W. Associated with these are striæ of feebler development, which vary in direction fully 10 degrees to the east and west of the heavy scorings, thus ranging from S. 34° to S. 54° W. An escarpment of the dipping layers which rises about 6 feet above the remainder of the quarry is glaciated not only on the upper surface and nearly vertical front, but also beneath one of the lower layers, its dipping under surface being smoothly polished for about 18 inches back from the front of the ledge. A

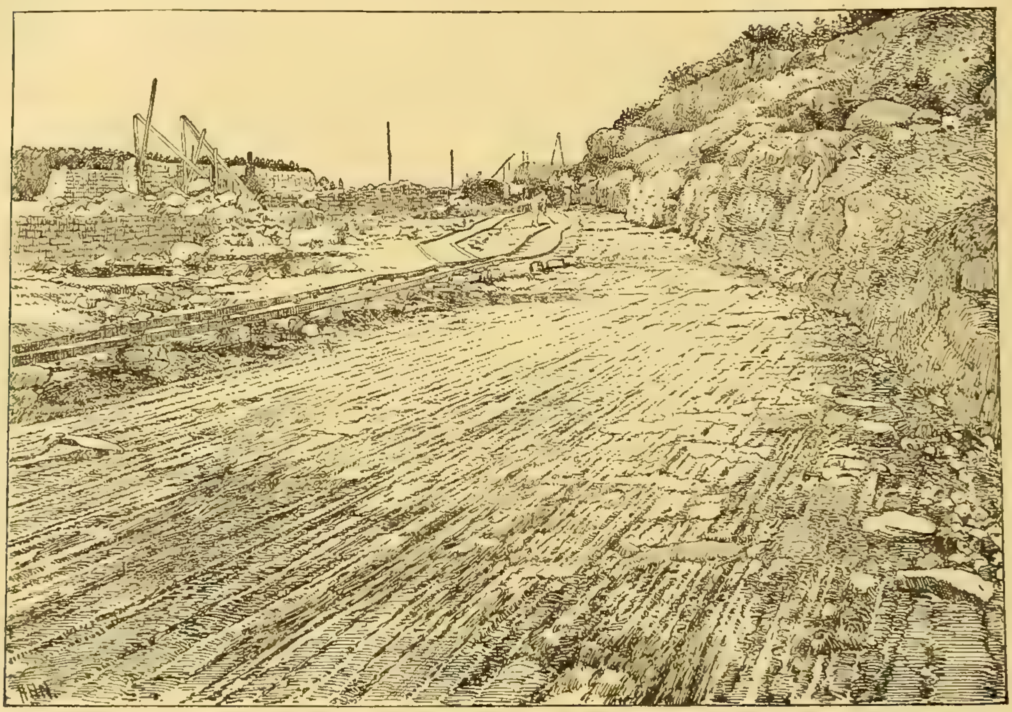
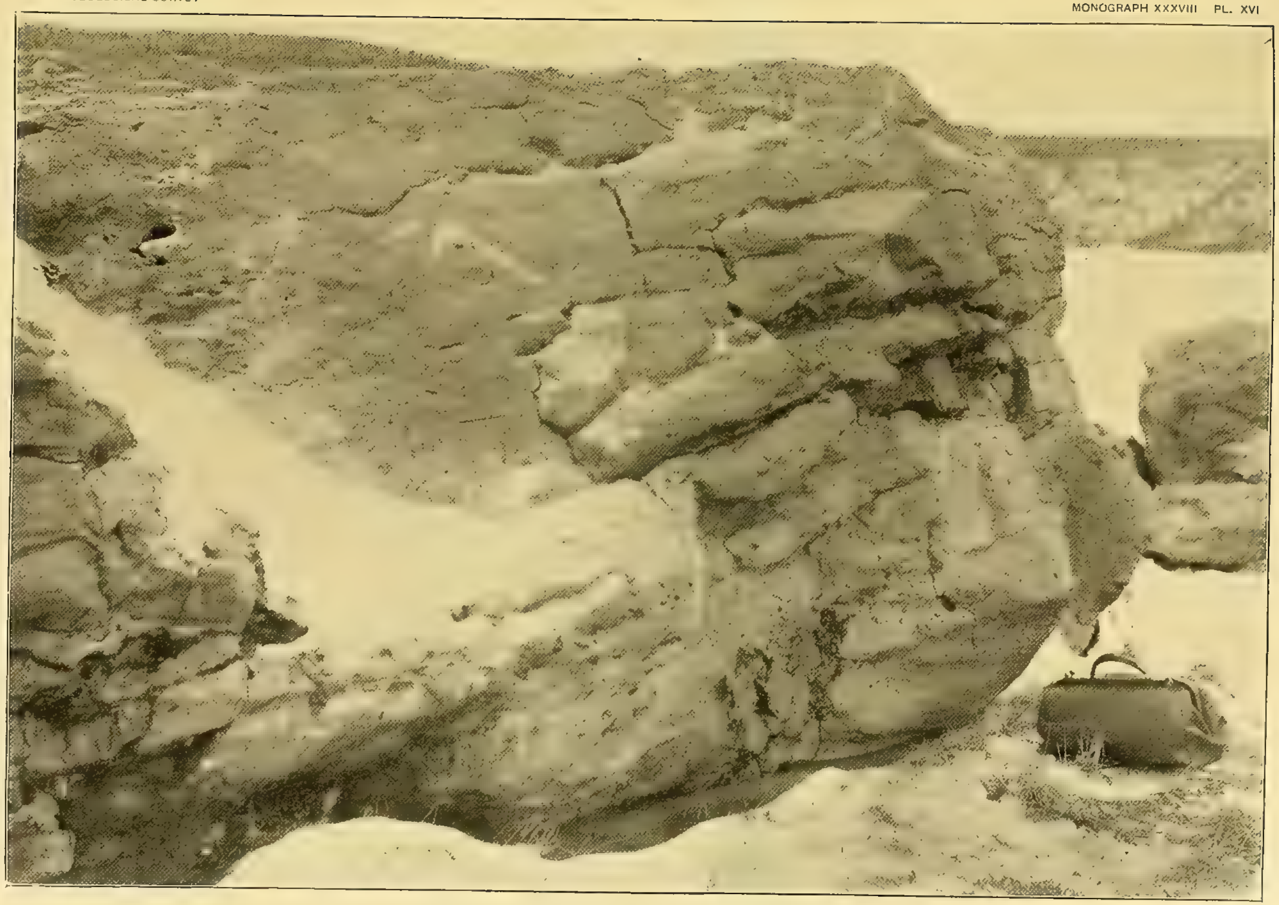


FIG. 2.—Glaciated surface in bed of Chicago drainage canal. [Drawing from a photograph taken by Chicago Drainage Commission.]

photograph of this ledge has been furnished by the Chicago Academy of Sciences (see PL. XVI).

A glaciated surface exposed near Lemont in the excavation of the Chicago drainage canal is represented in fig. 2, which has been drawn from a photograph taken by the Chicago Drainage Commission. The furrows are remarkably direct for a distance of several rods, and the planing is exceptionally smooth.

In the vicinity of Lemont the bed of the Chicago Outlet is extensively channeled by nearly parallel grooves several inches in width and depth and



STRIATION OF UNDER SURFACE OF LIMESTONE.

many rods in length. A photograph of an exposure made in the diversion channel of the Des Plaines is here furnished through the kindness of the

Fig. 3.—Grooves exposed by canal in bed of Chicago Outlet near Lemont, Illinois, apparently due to abrasion by pebbles transported by water in the outlet rather than to glaciation. [Drawing from a photograph by Chicago Drainage Commission.]

Chicago Drainage Commission (see fig. 3). These channels were announced in the Chicago newspapers to be glacial grooves, but they are apparently due to water abrasion rather than glacial scoring.

CHAPTER XI.

THE CHICAGO OUTLET AND BEACHES OF LAKE CHICAGO.

PREVIOUS WRITERS.

It is perhaps impossible to determine who was the first person to recognize the evidence or form the conception of a southwestward outlet from the Lake Michigan Basin to the Des Plaines Valley. Inquiry among the old residents of this region shows that many of them recognized the beaches as products of the lake, and they also noted that the lake once discharged into the Des Plaines Valley. Evidently these conceptions were entertained for many years before any notice appeared in scientific publications.

Bannister.—Probably the earliest scientific account of the outlet is that given by Dr. H. M. Bannister, in 1868, in the Geology of Illinois.[1] However, a report by the U. S. Army Engineers upon the survey of the Illinois River, by Col. James H. Wilson and William Gooding, was published the same year, which makes reference to the former southwestward discharge of Lake Michigan. Dr. Bannister opens his discussion of the old lake outlet and the raised beaches with the following statement:

> It is evident with a very little observation that, at a comparatively recent period, subsequent to the Glacial epoch, a considerable portion of Cook County was under the waters of Lake Michigan, which at that time found an outlet into the Mississippi Valley through the present channel of the Des Plaines.

Andrews.—One of the early publications of the Chicago Academy of Sciences presents a discussion of the beaches by Dr. Edmund Andrews, which has attracted wide notice.[2] The paper, however, deals mainly with the work of the lake at its present stage. The ancient beaches are briefly

[1] Geol. of Illinois, Vol. III, 1868, pp. 240–242.

[2] The North American lakes considered as chronometers of post-Glacial time, by Dr. Edmund Andrews: Trans. Chicago Academy of Sciences, Vol. II, 1870, article 1, pp. 1–24.

discussed, but the outlet is not described. A map accompanying the paper shows the approximate extent of the old lake beyond its present limits from the southern end northward some distance into Wisconsin and Michigan.

Chamberlin.—Prof. T. C. Chamberlin presented a brief discussion of the beaches along the Wisconsin shore of Lake Michigan in the Geology of Wisconsin,[1] which includes many important data concerning the shore phenomena and an interpretation of the lake history. In the twenty years which have elapsed since that report was published, the studies of the shores of the Great Lakes have brought out a more complex history than had been anticipated; hence the interpretation does not fully meet the case, though it recognizes important fluctuations of lake level.

Leverett.—Although, subsequent to the publications just noted, there have been frequent references in geological literature to the southwestward outlet and the ancient beaches, no publication especially devoted to them appeared until 1888, when a paper was published by the present writer in the Transactions of the Wisconsin Academy of Sciences.[2] This paper gives a somewhat detailed account of each of the several beaches found south of latitude 42° 30′, the latitude of the line of Wisconsin and Illinois. It contains but a brief reference to the outlet.[3]

Cooley.—Prof. L. E. Cooley, consulting engineer of the Chicago Drainage Commission, has published two papers which deal to some extent with the Chicago Outlet.[4] The first paper discusses the outlet as a means for improving the sanitary conditions at Chicago. The second paper deals with it as an important line for navigation, and discusses the proper means for obtaining the best results. This paper contains a large amount of valuable data concerning the regimen of the Illinois and Des Plaines rivers.

Marshall.—The report of the United States Army Engineers for 1890 contains much valuable material collected by Capt. W. L. Marshall concerning the Chicago Outlet as a channel for navigation; also references to earlier work by that organization.

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[1] Geology of Wisconsin, Vol. II, 1877, pp. 219-233.

[2] The raised beaches at the head of Lake Michigan, by Frank Leverett: Trans. of Wisconsin Acad. of Sciences, Vol. VII, 1883–1887, pp. 177–192. Published in 1888.

[3] It should be explained that the numerous typographical errors in the paper are due to the fact that the writer had no opportunity to correct the proof.

[4] Water supplies of Illinois in relation to health: Report of the Illinois State Board of Health, 1889. Lake and Gulf Waterway. Private publication, 1891.

Taylor.—Mr. F. B. Taylor has published in the American Geologist observations on high beaches in the northern porion of the basin of Lake Michigan.[1] These beaches, he thinks, pass beneath the present lake level before reaching the southern end of the basin. This being the case, they have no connection with the outlet under discussion.

Davis.—Prof. W. M. Davis has published a description of the Chicago Outlet in the Popular Science Monthly.[2] His paper was based upon a personal inspection of the channel with the United States topographic sheets in hand, and is a very clear, though brief, discussion of the features.

THE CHICAGO OUTLET.

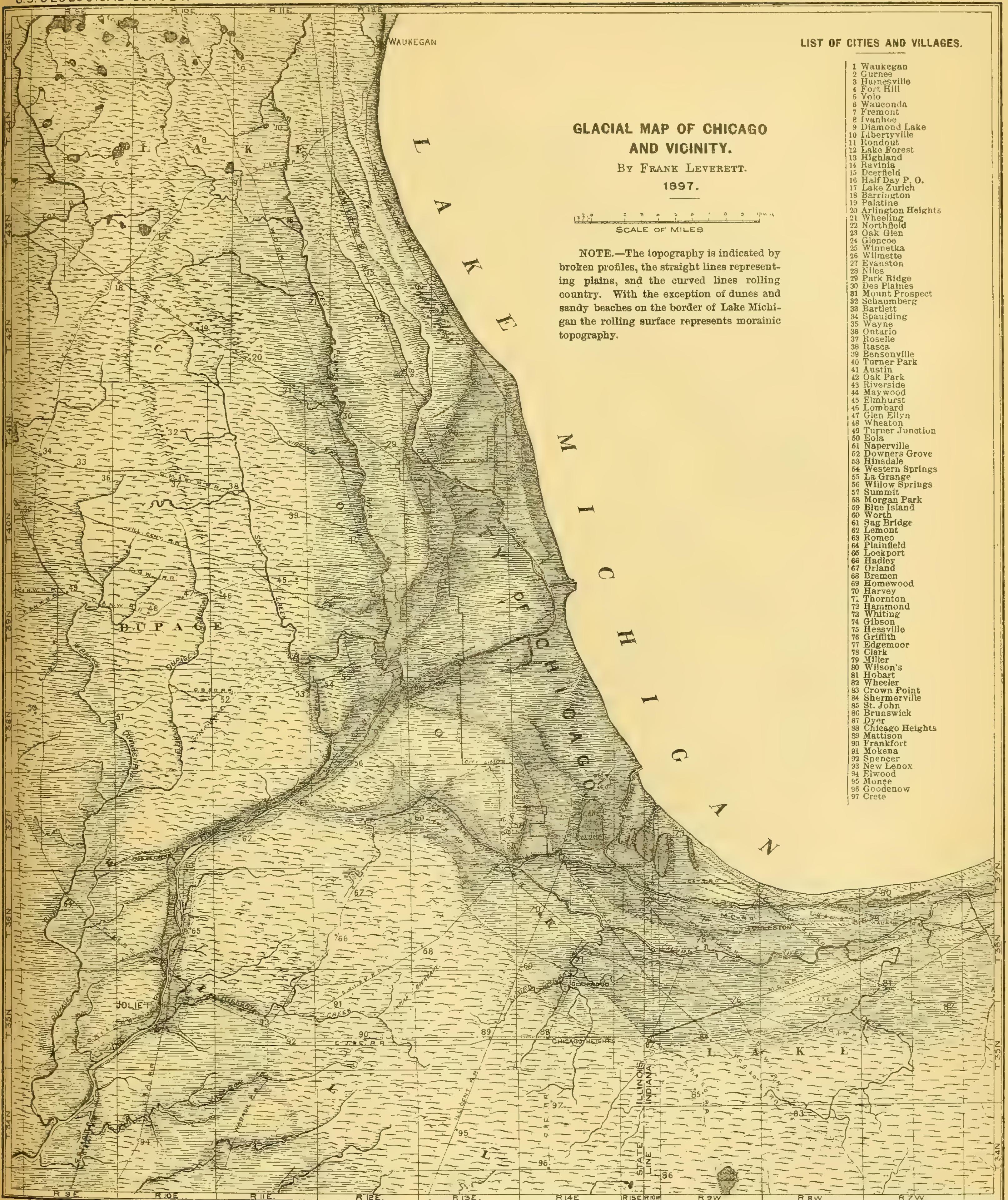
The name "Chicago Outlet" has come into use by geologists and engineers, without definite announcement or conference among writers, to designate the line of southwestward discharge from the basin of Lake Michigan across the low divides near Chicago and thence down the Des Plaines and Illinois to the Mississippi. It may appropriately embrace both points of discharge from the lake to the Des Plaines—namely, the one entering at Summit and the one at Sag Bridge.

When the lake was occupying the highest beach, the north or main outlet was entered about 3 miles southwest of Summit; when occupying the second beach, the outlet was entered at Summit; when occupying the third beach, the point of entrance appears to have been transferred eastward nearly to the present shore of Lake Michigan, as explained below. Similarly the southern outlet was lengthened eastward with the lowering of the lake, the point of entrance at the time of the highest beach being about 5 miles east of Sag Bridge, at the time of the second beach near Blue Island, and at the time of the third beach at Riverdale. This relationship of the several beaches to the outlets and the eastward lengthening of the outlets may be readily understood by a glance at the accompanying map (Pl. XVII).

There have been several surveys which have contributed contour maps of portions of the Chicago Outlet and of the plain covered by the lake in the vicinity of Chicago. The Chicago Drainage Commission have prepared an excellent map with 5-foot contours which covers nearly all of Cook

[1] American Geologist, Vol. XIII, May, 1894.

[2] The ancient outlet of Michigan, by Prof. W. M. Davis: Popular Science Monthly, December, 1894, pp. 218–229.



TOPOGRAPHY DEL. BY Wm. Kramer

County, and the immediate borders of the Chicago Outlet along the Des Plaines River. This has not been published, being merely a study map. The topographic work carried on by the United States Geological Survey in this region is largely published. The peculiar features of the upper portion of the outlet are brought out in an effective manner by the following sheets, viz, the Chicago, Riverside, Calumet, Des Plaines, Joliet, Wilmington, Morris, Ottawa, Marseilles, Lasalle, Hennepin, and Lacon sheets. These sheets cover something over 100 miles of the former lake outlet, or nearly one-third the distance from the head of the outlet to the Mississippi. The remainder of the outlet is shown in Prof. C. W. Rolfe's map sheets, yet unpublished. The reduced contour map (Pl. III) accompanying this report is based upon these several surveys. It serves to indicate the comparative size of the valleys occupied by the outlet and of the main tributaries of the Illinois. But to fully appreciate the features produced by the outlet, reference should be made to the large scale maps just mentioned.

In the interpretation of these features from the maps, care must be exercised in determining the condition of the valley at the time the outlet first became operative. The portion of the Illinois below Hennepin, it will be observed, is a preglacial valley, and was only partially filled by the glacial deposits. This filling is preserved in terraces along the borders of the valley. The glacial terraces seldom rise to a height of more than 100 feet and in the lower 100 miles their average height scarcely exceeds 50 feet above the present stream. In the portion of the valley above Hennepin the stream is mainly in a glacial or postglacial course, but even here there are complications which make it no easy matter to determine the amount of erosion attributable to the outlet. Before the accession of the lake waters this valley was the line of discharge for streams issuing from the ice sheet, as possibly of interglacial streams, some evidence of which has been gathered both by Professor Chamberlin and the writer. Although the streams were generally so heavily charged with detritus as to build up rather than erode their beds for some distance below the point of emergence from the ice sheet, it seems scarcely probable that filling would have exceeded erosion throughout the entire length of the Des Plaines and Illinois valleys. The basin at the head of the Illinois, as noted above, was apparently occupied by a lake at the Valparaiso substage of glaciation, and this would have received the greater part of the detritus borne down by the

glacial floods on the Des Plaines and other tributaries entering the basin farther east, thus permitting the water to issue at the western end of the basin, unburdened with glacial material. The stream discharging westward from this basin would, therefore, have a tendency to deepen the new valley opened across the Marseilles moraine, and in all probability would have extended its excavation at least through the new portion of the valley to Hennepin, there being in that section a gradient of several inches per mile and possibly at first a higher gradient. It seems not improbable, also, that some excavation was accomplished by the glacial floods in their passage over the terraces in the lower portion of the Illinois Valley, the advantages for erosion being as good for these floods as for the later ones fed by Lake Chicago.

It is also necessary to estimate the amount of filling which the lower course of the outlet has received since the lake waters were withdrawn. Concerning this filling, Prof. L. E. Cooley has made some investigation and concludes that from Peru to Peoria it will average 30 feet, and is appreciable to the mouth of the Illinois, though probably somewhat less toward the mouth of the river.[1]

In the Des Plaines Valley the erosion of the Valparaiso moraine and of the terraces outside of it was probably very largely effected by the lake waters. An examination of this portion of the outlet will therefore be likely to afford a fair understanding of the size of the channel which it formed.

From the topographic maps it appears that the bed of the lake outlet declines from about 590 feet at Lemont, in the midst of the Valparaiso system, to scarcely 500 feet at the head of the Illinois, or 90 feet in a distance of 25 miles. Of this fall, 76 feet is made in a little less than 10 miles, from Romeo to Joliet pool. The glacial terraces which border the outlet decline from about 630 feet to 570 feet between Lemont and the head of the Illinois. This deepening of the channel is shown by the maps to be somewhat irregular, ranging from 40 feet to about 70 feet, but an average erosion of 50 feet may be assumed. This deepening embraces not only the work at the time the upper beach was forming, but also that carried on during the formation of the second and third beaches, or down to the time of the final abandonment of the lake outlet. The channel above Joliet has

[1] Communicated to the writer.

a breadth of 1 to $1\frac{1}{2}$ miles, averaging perhaps $1\frac{1}{4}$ miles. Between Joliet and the head of the Illinois several island-like remnants of the glacial terraces are preserved in the midst of the channel, making it more difficult to estimate the breadth, but it is not markedly greater than in the portion above Joliet. The portion above Joliet is cut to a slight depth into the Lockport (Niagara) limestone, which there underlies the glacial gravel. The excavation in limestone, however, amounts to not more than one-fourth the size of the channel, for the limestone seldom rises more than 40 feet above the bed of the lake outlet, and in many places its surface comes down nearly to the level of the valley floor. Below Joliet there was even less excavation in the rock than above. It is estimated that the rock excavation there does not exceed 10 per cent of the total cutting.

In the low tract at the head of the Illinois (the Morris Basin) the depth of the excavation by the outlet is very slight, averaging probably less than 20 feet in the 10 miles between the head of the Illinois and Morris. The plain appears to have descended nearly to the 520-foot contour on the borders of the river before modified at all by lake or stream action. A low bluff formed on the north border of the basin has a height of 15 to 20 feet. On the south border there is no bluff, that side of the basin being heavily coated with sand deposits. These deposits may perhaps have been laid down in part at the time the lake waters were forming the outlet, but they are probably largely of earlier date. In this basin the lake outlet has an average width of 4 or 5 miles.

In the section of the Illinois immediately below (west from) this basin, erosion prior to the opening of the Chicago Outlet probably had brought the level of the valley bottom down to that of the upper beach line of the basin, 550 to 560 feet above tide. The bed of the Chicago Outlet is nearly 500 feet, thus leaving about 60 feet subsequent depth of erosion. Passing westward the broad bed of the Chicago Outlet declines nearly 60 feet in the 40 miles between the west border of the basin, just mentioned, and the bend of the Illinois near Hennepin. Whether the valley had the same gradient at the time the accession of lake waters occurred is not known, but it could not have been greatly different, for the glacial terrace just above Hennepin stands about 30 feet lower than the beach lines of the Morris Basin, and this terrace in all probability had been eroded the remaining 30 to 40 feet necessary to give a similar gradient.

The width of the outlet between Morris and Hennepin averages about $1\frac{1}{2}$ miles. The excavation is largely in soft St. Peter sandstone, there being nearly continuous rock bluffs to a height of 60 to 75 feet above the level of the bed of the outlet. This sandstone and the Coal Measures sandstone which in places overlies it present much less resistance to stream action than the firm Lockport (Niagara) limestone. The resistance may not be markedly greater than that of the beds of glacial drift.

As noted above, the level at which excavation by lake waters began in the section below the great bend of the Illinois is less than 100 feet above the present stream, since the glacial terraces in which the lake outlet was excavated seldom reach a level 100 feet above the bed of the outlet, while below the mouth of the Sangamon they rise scarcely 50 feet above that level. If the 30 feet of filling estimated by Professor Cooley be added, it seems a liberal estimate to allow 75 feet of average excavation in this lower section of 200 miles. It may not have been more than two-thirds that amount. The width of the outlet in this lower section ranges from 2 up to about 5 miles, with an average of perhaps 3 miles. This excavation is in a loose, easily eroded bed of sand and fine gravel, which had been deposited largely by glacial streams.

Summing up the above estimates, it appears that the outlet has a width ranging from 1 mile up to about 5 miles, and a depth ranging from 20 feet up to 70 feet. Its length from Summit to the mouth of the Illinois is 300 miles. The excavation is probably not less than 3 cubic miles. With the exception of about 15 miles between Lemont and Joliet and 40 miles between Morris and Peru, where rock strata have been eroded, the excavation is almost entirely in beds of drift. The width varies with the resistance to erosion, being least in the section where the resistant limestone was eroded and greatest where there were only drift beds to remove, while in the sandstone the channel is of intermediate breadth. The breadth is also to some degree dependent upon the slope of the bed, being narrower in the portions with rapid fall than in portions having a low rate of descent.

Throughout the entire length of the outlet the bluffs are steep, like a river bank, and deposits made by side streams on the edge of the valley are very meager—a feature which indicates that the stream had great volume, probably filling the channel from bluff to bluff, and a current suffi-

ciently strong to carry away nearly all the detritus brought into it by the side streams

The rapids between Romeo and Joliet occur in a section where the limestone is friable, and it is thought by Professor Cooley that the friability is such that falls could not have been maintained, or even established. The removal of the existing rapids, the main barrier in the course of the outlet, it is estimated, would require the excavation of a channel in rock only about 20 miles in length and 25 to 75 feet in depth. This excavation would be about ten times that accomplished by the lake outlet in that part of its course. Being the outlet from a lake, the amount of sediment carried by its waters is a matter which should be weighed in discussing the slight amount of excavation.

Professor Cooley has called the writer's attention to the deposits at the head of Lake St. Clair as likely to furnish an index of the amount of sediment transported by the Chicago Outlet. A delta with an area of several square miles has been built in the head of Lake St. Clair, which must have derived the bulk of its material from southward-moving littoral currents along both the borders of Lake Huron. In the lake under discussion littoral currents along the west border would have transported material probably in as great volume as on either shore of Lake Huron, but those on the east and south may have contributed less, for wind drifting there is very effective. It seems legitimate to assume that at least half as much sediment was being transported down the Chicago Outlet as is carried by the St. Clair River. From this it appears probable that the waters of the Chicago Outlet were somewhat less turbid than the St. Clair. Professor Cooley thinks the contributions of sediment to the outlet through the Des Plaines were of little consequence, for this river has, since the lake waters were withdrawn, made scarcely any filling of the outlet below Riverside, where its delta would naturally accumulate. The accession of larger tributaries below may have rendered the stream slightly more turbid than on the rapids

It should not be inferred that this outlet is entirely free from river débris. Beginning at the upper beach, near Summit, there is for several miles a mass of coarse material, largely limestone blocks, too large to have been transported by the current, covering the bed of the outlet. The Drainage Canal exposes excellent sections of the coarse river débris from Summit to Lemont, there being only limited areas in this interval where

the solid rock comes to the surface. Below Lemont the bare rock forms much of the floor as far as Joliet. From Joliet to the head of the Illinois perhaps half the floor is covered with deposits of drift and river débris, so that the distance to rock is not known. The remainder is either bare rock or rock with a very thin deposit of coarse river débris, with a liberal supply of bowlders of Canadian derivation. In the Morris Basin the rock is largely shale. This has been eroded in places by the current, and the hollows have been filled with sand. From the Morris Basin to the bend of the Illinois the rock floor, mainly sandstone, is generally swept clean. The St. Peter sandstone of this section is of such a texture as to break up rapidly into its constituent grains, and these, as fast as they were set free, would have been carried by the strong current down to the lower Illinois, and probably on into the Mississippi. The lower Illinois has only sand and silt in its bottoms. This section is now in process of silting up, the current being too sluggish to carry away the material brought in from the upper portion of the stream.

Accumulations of bowlders should be mentioned in connection with the river débris. The most conspicuous accumulation noted is that on the borders of the Sag outlet, just east of the point where it enters the Valparaiso morainic system and northeast of the village of Worth. An area of perhaps a square mile is so thickly strewn that one might almost step from stone to stone over its entire extent. There are, it is estimated, more than 1,000 bowlders per acre. Surface bowlders are not rare in other portions of the old lake bottom where sand deposits are thin or wanting, there being, perhaps, 200 per square mile on the part of the lake bottom where till is exposed. There seems, however, to be a tendency to aggregation at the entrance to the old outlets. This feature suggests that floating ice has been influential in their distribution, though there may have been a large number brought by the ice sheet, the head of the outlets being near the inner border of the Valparaiso morainic system.

Some very large bowlders have been found along the Drainage Canal. The large ones occur in most abundance where the Valparaiso system is crossed by the lake outlet. Bowlders are also very numerous for a few miles above the junction of the Des Plaines with the Kankakee. They seldom reach the large size which bowlders in the Valparaiso system present.

THE GLACIAL LAKE CHICAGO.

The name "Lake Chicago" was introduced by the writer in a recent bulletin issued by the Chicago Academy of Sciences.[1] The need for a name for this glacial lake and the reason for the selection of this name are set forth in the following statement:[2]

> The introduction of the name "Lake Chicago" for the glacial lake which was held in the southern end of the Lake Michigan Basin seems convenient, if not necessary, inasmuch as its area was not coincident with that of Lake Michigan and its outlet was in the reverse direction. It is also in keeping with the custom of students of glacial lakes, who find it advantageous to employ a special name for each of the temporary bodies of water in the several basins. The name "Lake Chicago" seems especially pertinent, since the glacial lake extended about as far beyond the present limits of Lake Michigan in the vicinity of Chicago as at any part of its border. It is also a name which readily suggests the position of the lake, and it is in keeping with the name which has come into use for the outlet, namely, the "Chicago Outlet."
>
> The name "Lake Chicago" is applied provisionally to all the stages at which there was a southwestward outlet, but it is not yet certain whether they were all formed during the occupancy of a portion of the Lake Michigan Basin by the ice sheet.

The precise relations of these beaches to the ice sheet, or points of connection with it, have not as yet been determined. The writer's study has been carried no farther north than to the line of Wisconsin and Illinois on the west side and to Grand River on the east side of Lake Michigan. Professor Chamberlin's studies left the precise extent of the higher beaches undetermined. Mr. Taylor's observations have been confined to the northern portion of the basin, and as yet no one has examined the intervening districts, where it appears probable that the higher beaches terminate. Probably the most favorable field for investigation will be found on the Wisconsin side, since extensive deposits of wind-drifted sand on the border of the lake in Michigan make it difficult to determine the extent of water action. The long stretches of high bluff, however, interrupt the beaches so greatly that some difficulty is anticipated in making precise correlations on the Wisconsin side.

Enough is known to make certain that the general direction of retreat of the ice sheet was northeastward. The southern and western portions of the Great Lake basins were, therefore, the first to become free from ice and

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[1] The Pleistocene features and deposits of the Chicago area, by Frank Leverett: Bull. No. 2, Geol. and Nat. Hist. Survey, Chicago Academy of Sciences. Issued May, 1897.

[2] Op. cit., p. 65.

to be occupied by glacial lakes. While the ice sheet was covering the present outlets of Lakes Superior and Michigan, these lakes had no connection with each other, nor with the lakes to the east, and their discharge was southward or southwestward into the Mississippi, from the present heads of these lakes. A small district west of Lake Erie was also occupied by a lake that discharged southwestward to the Wabash. Upon the withdrawal of the ice sheet from the southern peninsula of Michigan and the southern portion of the Lake Huron Basin, the lake at the western end of Lake Erie became expanded and a line of discharge was opened eventually from Saginaw Bay across the southern peninsula of Michigan to the Lake Michigan Basin, and this being lower than the outlet to the Wabash, that outlet was abandoned. The waters of the Lake Huron Basin being held at a somewhat higher level than those of the Lake Michigan Basin, the flow of water was from the former to the latter. The glacial lake which discharged across the southern peninsula of Michigan extended over the district between Lake Huron and Lake Erie, as well as the Lake Erie Basin and the low district bordering it on the south and west. It apparently did not extend far into the Ontario Basin, as a study of moraines indicates that the ice sheet occupied that basin at the time of this discharge. It thus appears that the Chicago Outlet at one time was the line of discharge for an area much larger than the present Lake Michigan Basin.

Three well-defined beaches have been recognized at the southern end of the Lake Michigan Basin above the level of the present beach, which are known as the Upper or Glenwood beach, the Second or Calumet beach, and the Third or Tolleston beach.

THE UPPER OR GLENWOOD BEACH.

This beach receives its name from the village of Glenwood, on the Chicago and Eastern Illinois Railroad, a few miles south of the limits of Chicago. The name has been selected (1) because the beach is especially well developed at that village, and (2) because, being near the State line of Indiana and Illinois, the name will be familiar to residents of either State.

In the Illinois portion of Lake Chicago this beach is present, except for a few miles between Waukegan and Winnetka, where the lake shore is now farther west than it was at the time this beach was formed. In Indiana the beach is present throughout the entire extent of the border of

Lake Chicago in that State, being nowhere less than 2 and in places 12 miles back from the shore. In Michigan it is absent for a short distance at the "clay banks," north of New Buffalo, where the present shore stands farther east than the shore of Lake Chicago. It is also absent for the same reason for a few miles near the line of Berrien and Van Buren counties, north of St. Joseph, Michigan. Tracing in detail the course of this beach is as follows:

From the Wisconsin line southward to South Waukegan it stands only 1 to 2 miles back from the shore of Lake Michigan and comes out to that shore at the point where the bluff of till sets in south of Waukegan. This bluff of till stands above the highest lake level as far south as Winnetka. From Winnetka a cut bank, nearly 20 feet in height, extends south along the face of the east till ridge noted above to its terminus, perhaps 1 mile from the point where the old shore departs from the present shore of the lake. From the terminus of this ridge a bar was built out southwestward 5 or 6 miles, terminating about a mile east of Chicago River, in the western part of T. 41, R. 13 E. The bar sends out two prominent spurs to the west, a distance of nearly 1 mile. These probably mark the termini in its early stages of growth. The average width of this bar is about one-fourth mile, and it was built up to a height of 10 to 20 feet above the bottom of the bay back of it. It consists largely of gravel, but has a liberal admixture of sand. The bay back of this bar extended to the valley of the Chicago River and has a width of 2 to 3 miles. The northern end finds a narrow extension northward in Skokie Marsh. The site of this old bay is now largely under cultivation, though some portions are still marshy.

The question naturally arises whether this accumulation of gravel and sand was formed by the lake currents and waves independent of the Chicago River, or was largely formed as a delta from that stream. This deposit is not in the form of a delta built up at the debouchure of the river into the lake, but lies some distance to the east of the river valley, thus indicating that it was formed by the lake. Moreover, to make it still more evident that it was the lake and not the river which contributed the great bulk of the beach deposit, it is found that the river valley above the point where it entered the old lake has very little assorted material, such as would accumulate above a delta.

The beach appears on the west side of the Chicago River, in sec. 19, T. 41, R. 13 E., about a mile northwest from the terminus of the bar. From this point southward to Oak Park the shore is usually a cut bank ranging from 6 to 25 feet in height, with occasional deposits of beach gravel and sand along its front. At Oak Park there is an extension of gravel down the east side of the Des Plaines River similar to that of the bar east of the Chicago River noted above. A ridge or bar 20 to 40 rods in width and 10 feet or more in height extends from Oak Park south about 2 miles to the south part of secs. 13 and 14, T. 39, R. 12 E., and there terminates abruptly with a level nearly 20 feet above the plain on its immediate borders.

Passing to the west side of the Des Plaines River, the beach appears about a mile above the southern end of the bar just described, and passes in a curving course westward through the south edge of Maywood, in secs. 14, 22, and 16, T. 39, R. 12 E. This portion of the beach is only 2 to 4 feet in height, and at the west it fades out completely. Its faintness in this district is probably due, in part at least, to the protection from wave action occasioned by the bar just described. Upon passing south and crossing Salt Creek, about a mile from the point where the beach fades out, it reappears as a well-defined ridge, composed of sand and gravel, rising from 10 to 12 feet above the border of the plain on the east, and having a breadth of 30 to 40 rods. Following this beach southward, it changes in about a mile to a cut bank, which is well defined from that point southward to the lake outlet, a short distance south of Lagrange. Its course is through the east part of the city of Lagrange, where it is in the form of a cut bank 10 to 15 feet in height.

Passing to the west side of the outlet, near Willow Springs, the shore line is found as a cut bank along the east face of the prominent morainic tract which occupies the interval between the two outlets of the lake. Though mainly a cut bank, the beach is represented occasionally by deposits of gravel and sand.

South from the southern or Sag outlet, the shore is carved on the inner face of the Valparaiso moraine with banks 5 to 20 feet or more in height, but with only occasional deposits of gravel and sand. Upon approaching the State line, however, near Glenwood, the shore bears away from the moraine, and deposits of gravel and sand are built up to a height of 6 to 12 feet or more. These are sometimes in the form of a single ridge,

but not infrequently a series of parallel ridges occur, separated by narrow sags.

The effect of the waves at this lake stage is discernible on the borders of Blue Island till ridge, though the western border is characterized by dunes which conceal to some extent the action of the lake.

The beach enters Indiana near Dyer and passes eastward through the center of the village. It stands about 10 feet above the plain bordering it on the north and is 30 to 40 rods in width. Within 2 miles east of Dyer it reaches a height of 25 or 30 feet, there being wind-drifted sand along its crest. Eastward from there to a point about 1½ miles east of Schererville it maintains a height of 20 to 30 feet and width of 40 to 60 rods. It then curves toward the northeast and dies out in less than a mile. Continuations are, however, found in the district to the north. About a mile north from its east end a small ridge sets in, which leads eastward, passing south of Griffith. A larger ridge sets in on the south side of Cady Marsh west of Griffith and leads eastward through that village. It soon becomes a belt of sand one-half mile or more in width, with several parallel ridges, and this belt extends in a course north of east through Ross, Liverpool, and Chrisman, and comes to Calumet River about 2 miles northeast of Chrisman. The Second or Calumet beach is closely associated with it from the vicinity of Ross to Chrisman. From Calumet River the two beaches lead northeastward nearly parallel with the present shore of Lake Michigan, and distant 2 to 3 miles from it, to Trail Creek near Michigan City, beyond which there is considerable complexity, as shown below.

The belt of sandy ridges whose course has just been outlined apparently did not form the extreme southern limits of Lake Chicago, but inclosed or shut in bays of considerable size on the south border. One of these bays extended south into the Deep River Basin several miles beyond the sand belt, its south border being 2 or 3 miles south of Hobart. From this bay there was apparently a westward connection with the lake along the valley of Turkey Creek between a till ridge noted above and the north border of the Valparaiso morainic system. In places a cut bank 3 to 5 feet high has been formed on the slopes of these bordering moraines.

Another bay was formed in the Salt Creek drainage basin, which extended 3 or 4 miles south of the belt of sand ridges. This was separated from the bay in the Deep River Basin by the till ridge which leads north-

ward from near Wheeler to the south border of the sand belt near Chrisman. From Salt Creek Basin a bay or marsh extended up Calumet River, probably about to the east line of Porter County, a distance of 10 miles or more. Its connection with the open lake appears to have been along the line of Calumet River. In this bay and also the one in the Deep River Basin wave action was not strong enough to form continuous well-defined shores, yet cut banks 3 or 4 feet in height were noted at several places on their borders, and there is a thin coating of sand over much of the area covered by the bays. East of Hobart the sand presents low ridges 5 to 10 feet high and 10 or 12 rods wide, trending nearly north to south. These are developed only over 1 or 2 square miles.

A bay also occupied east and west Trail Creek valleys and connected with the open lake along the valley of the main Trail Creek. This bay was shut off from the main water by the till ridges which follow the north side of these streams. Its outlet into the lake is bordered in places by a sandy ridge running northward parallel with Trail Creek. The best developed ridge is on the west side of the creek, in secs. 11, 2, and 3, T. 37, R. 4 W., where it has a height of 10 or 12 feet and is maintained for a distance of 2 or 3 miles. There is a deposit of sand several feet in depth covering the bottom of this bay. It may have been derived in large part as a wash from the steep bluff-like border of the Valparaiso moraine, which lies immediately south.

From the valley of Trail Creek, near Michigan City, Indiana, northeastward to Galien River near New Buffalo, Michigan, a distance of 6 or 7 miles, it is difficult to locate the upper beach. There are several short sandy ridges separated by swamps and marshes, but not a continuous well-defined belt of sand, such as is developed farther west. In some cases the sand ridges are evidently wind-drifted, and probably they are largely modified by wind. They occur not only on the slope between Covert till ridge and Lake Michigan, but also along the crest of that ridge, reaching an altitude 75 feet or more above Lake Michigan. In a few places gravel deposits were noted on the inner slope of the till ridge at an altitude as high as 30 feet above the lake. They are well displayed along the main street in New Buffalo leading southwest from the post-office. There is also a good exposure southeast of the Methodist church, the depth of gravel being several feet. In the vicinity of the public school building there are

sand deposits several feet in depth, which are slightly pebbly near the bottom.

North of Galien River, about 2 miles from New Buffalo, in sec. 36, T. 7 S., R. 21 W., a well-defined gravel ridge sets in, which leads north about a mile to the shore of Lake Michigan. It is 6 or 8 feet high, 20 to 30 rods in width, and stands by surveyor's level 55 to 58 feet above Lake Michigan.[1] This appears to be the upper beach notwithstanding that sand deposits on neighboring portions of Covert Ridge occur at 90 to 100 feet above the lake. The presence of the sand at these higher levels seems referable to wind transportation.

For a mile or more north from the point where this gravel beach comes to the lake, Covert Ridge forms the immediate bluff and rises nearly 90 feet above lake level. A gravelly beach appears on its northwest slope at the lake bluff, in sec. 19, T. 7 S., R. 20 W., and bears north of east to Lakeside Station, on the Chicago and West Michigan Railway. The gravel has an altitude at this station very nearly 60 feet above Lake Michigan, but in connection with it there are sand deposits which increase the altitude of the beach to nearly 70 feet above the lake. For a mile or more northeast from Lakeside the beach lies a short distance east of the railway. It then crosses to the west side, but is within a half mile of the railway for several miles north. At Sawyer Station it is about as far west of the railway as at any point, while at Bridgman it is along the railway track. It usually presents a definite gravelly ridge a few feet high, capped in places by sand deposits several feet in depth. The gravel seems to hold a uniform altitude about 60 feet above Lake Michigan.

A sharp sand ridge follows the crest of Covert Ridge for a few miles in the vicinity of Bridgman and becomes united with this beach about midway between Bridgman and Stevensville. From that point to St. Joseph the sand deposits are so heavy as to conceal the beach line. The sand in places has a depth of 20 or 30 feet and is most prominent along the crest of Covert Ridge. A short distance southeast of Bridgman it passes down the outer slope of Covert Ridge in a definite belt and extends to the valley of Galien River, near New Troy. The continuity of this belt of sand is remarkable, especially since it lies in places a mile or more east

[1] Elevations determined by Mr. Glavin, formerly county surveyor.

of the upper beach. In all probability it was deposited by wind, for it reaches in places an elevation 125 feet above the lake, or about 60 feet above the upper beach. It has a range also of fully 60 feet in its elevation.

While the beach was forming along the inner face of Covert Ridge in southern Berrien County, Michigan, there were probably bays or marshes occupying the low land back of the ridge, for this in places scarcely rises to the level of the beach. An examination of the plains drained by Galien River brings to light only a slight sand coating and little, if any, evidence of wave cutting. The greater part of the plain stands so near the level of the upper beach that there were probably only marshes at the highest lake stage. The sand may have been deposited by wind or perhaps by a small lake held between the ice border and the Valparaiso morainic system. In a plain between the outer till ridge and the Valparaiso system near the village of Baroda, there appears to be slight wave cutting, both on the border next to the Valparaiso system and the east border of the outer till ridge at an elevation nearly 20 feet above the level of the upper beach as developed on the inner slope of Covert Ridge. There are also conspicuous deposits of sand to a height of 10 feet above that beach, or about 70 feet above Lake Michigan. This determination led the writer to make examinations along the base of the Valparaiso system farther north and also of the borders of the till ridges toward the north and west with a view to fixing the highest limit of wave action and ascertaining, if possible, whether the greater height of wave action on this plain is due to a small lake held between the ice front and the Valparaiso system, or to a stage of Lake Chicago somewhat higher than the supposed upper beach on the slope of Covert Ridge.

An extensive gravelly plain, apparently a delta, is found back of Covert Ridge on the border of the St. Joseph River. The greater part of this delta stands 50 to 60 feet above Lake Michigan, or sufficiently low to be connected with the 60-foot beach of Lake Chicago. In the midst of the Valparaiso morainic system the river is bordered by a gravel terrace which descends from about 100 feet above the lake at Niles to 80 feet at Berrien Springs, and to about 70 feet at the point where it expands into the delta. On the border of this terrace below Berrien Springs, in secs. 1 and 2, T. 6 S., R. 18 W., there are occasional basins 8 or 10 feet in depth, occupying an acre or more each, whose rims stand only about 80 feet above Lake Michigan. These basins apparently stand above the level of the highest stage of Lake

Chicago; otherwise they would have been obliterated by its waves. They seem to oppose the view that a small lake held between the ice border and the Valparaiso system had an elevation much greater than that of the supposed upper beach of Lake Chicago. It seems not improbable that such a lake may have stood 15 or 20 feet above that beach, but it scarcely could have exceeded these limits. By combining the evidence from the St. Joseph Valley and the wave-washed plain near Baroda, one is inclined to consider the wave action displayed on that plain the product of a small lake held between the ice and the Valparaiso system rather than a stage of Lake Chicago higher than that which formed the well-defined beach on the inner slope of Covert Ridge.

There appears to have been a bay extending up the Pawpaw River Valley at the highest stage of Lake Chicago nearly to the village of Hartford. It appears not to have reached the site of that village since the low plain bordering the river is found to carry well-defined basins several feet in depth. One basin in the east part of the village occupies 5 or 6 acres and has a depth of about 8 feet. Near Coloma wave action along the base of the moraine, south of Pawpaw River, seems to have reached an altitude about 650 feet above tide, or 70 feet above Lake Michigan. It has about the same altitude immediately south of Watervliet. These lines of wave action are only about 15 feet lower than the plain containing basins noted at Hartford.

There are a few exposures of gravel in St. Joseph at about 60 feet above Lake Michigan, but from St. Joseph northward for several miles Covert Ridge forms the bluff of the lake. Near the line of Berrien and Van Buren counties it bears away from the lake, and beach deposits are formed on its inner slope a mile or more west from the crest. They consist largely of sand, there being only occasional small pebbles. It is not possible, therefore, to determine so definitely as in southern Berrien County the upper limits of the lake. The evidence, however, seems satisfactory that the lake reached an elevation nearly 70 feet above the present level of Lake Michigan.

For a few miles north of South Haven, Covert Ridge again forms the bluff of the lake and rises above the level of the upper beach, but in sec. 25, T. 1 N., R. 17 W., in Allegan County, exposures of gravelly sand were found on its slope at about 60 feet above lake level. Gravel is reported to

have been found near Pier Cove at the base of sand dunes, at a slightly higher level than 60 feet, but this place was not visited by the writer. North from the mouth of the Kalamazoo River only a brief reconnaissance was made, so that the full extent of the beaches has not been ascertained. A very strong beach appears immediately east of Holland, on the south side of Black River, at an altitude 60 to 65 feet above Lake Michigan. This beach appears also in Zeeland. Evidence of wave or current action at a higher altitude is found a few miles east and south of Zeeland on the slopes of Covert Ridge. A wave-washed surface is found at an altitude about 100 feet above Lake Michigan, in the vicinity of Vriesland, and northward from there to the border of Grand River. Passing southwestward from Vriesland a sandy belt is found at a still higher level, its upper limits being about 120 feet above the lake. This sandy belt is well displayed at Overisel and Filmore Center and is traceable for several miles along the inner slope of Covert Ridge. It has a definite ridging, as if marking the border of the lake, but may possibly have been drifted a few feet above the water level. In that case the water level here may have been about the same as at Vriesland, or very nearly 100 feet above Lake Michigan. Further study is necessary to a satisfactory interpretation of the phenomena, since neither of the two beaches mentioned has been traced into definite connection with the upper beach farther south. Possibly the wave action displayed on the slope of Covert Ridge east and south of Zeeland is that of a small glacial lake contemporaneous with the formation of Zeeland till ridge. The general weakness of the beach would seem to favor this interpretation. An alternative hypothesis would refer its high altitude to northward differential uplift and make it constitute the continuation of the upper beach of Lake Chicago. In that case the strong beach standing at 60 to 65 feet would be the continuation of the Second or Calumet beach of Lake Chicago. This matter is discussed more fully below.

There are extensive sand plains in Allegan County, Michigan, between the Valparaiso morainic system and Covert Ridge, known as the "Pine Plains," which probably throw some light upon the altitude of the highest stage of Lake Chicago. The plains are traversed nearly centrally by the Kalamazoo River and extend north to Rapid River. Between Kalamazoo

and Rapid River the altitude is 75 to 90 feet above Lake Michigan. The portion south from the Kalamazoo River ranges in altitude from 70 feet to fully 100 feet above the lake, being highest on the south border. The sand ranges in depth from a foot or two up to fully 50 feet and appears to be thickest on the borders of the Kalamazoo River. If we except the southern border, the sand deposition seems largely referable to a delta accumulation made by Kalamazoo and Rapid rivers, beginning, perhaps, while the ice sheet was forming Covert Ridge and continuing through the formation of the upper beach of Lake Chicago. The altitude of much of the sand plain is such as to correspond somewhat closely with that of the upper beach in neighboring portions of Van Buren County, being about 70 feet above the lake. The water level could not well have stood higher than 90 feet for any prolonged period, for basins were observed on the east border of the sand plain near Swan Creek, at 90 to 100 feet above Lake Michigan. Probably a portion of the sand, especially that on the somewhat elevated south border, was deposited in connection with the withdrawal of the ice sheet from the Valparaiso morainic system. A small portion also may have been brought in as a wash from neighboring portions of the Valparaiso morainic system, which here consists of a sandy till which might easily furnish a large amount of sand upon erosion. The bulk of the deposit, however, appears to be referable to the Kalamazoo River and the small neighboring stream, Rapid River. This being the case, the lake level may be confidently placed at fully 70 feet and possibly may have been 90 feet in western Allegan County. The latter elevation would fall in well with the elevation of the wave-washed surface in southern Ottawa County, 100 feet above the lake.

Reviewing the preceding statements concerning the altitude of the upper beach, it appears that there is little variation in altitude from northern Cook County, Illinois, around the head of Lake Michigan, to St. Joseph, Michigan, the elevation being usually between 55 and 60 feet above the lake. Upon passing northward from St. Joseph, the evidence from river deltas seems to support the view that there has been a slight differential northward uplift, but is not considered conclusive. The western shore of the lake has not been examined sufficiently to afford a basis for comparison. One observation near Waukegan shows what appears to be wave action at

a higher level than that of the upper beach at the point where it comes to the lake in northern Cook County, the altitude being about 90 feet above the lake. But observations by the writer in northern Lake County, Illinois, and by Professor Chamberlin in southeastern Wisconsin indicate that the upper beach continues at about 50 or 60 feet above Lake Michigan.

A few gravel pits have been opened in the upper beach in the vicinity of Chicago. Probably the most extensive is Haas's pit, near Forest Home Cemetery, 1 mile south of Oak Park. This is opened in the bar described above as leading southward on the east side of the Des Plaines River. The excavation extends from the east side of the bar west past the center, and shows beds dipping at various angles, but all toward the east. The lower bed, which is mainly sand, decreases in thickness in passing from the higher to the lower part of the bar. The overlying beds are thin on the higher part and increase in thickness toward the east border of the bar. The coarser deposits appear to be built upon the sand bar, as may be seen by the following section. Mr. Haas states that the material of the same bed may vary greatly in coarseness within the space of a few feet, but that throughout the entire extent of the pit, which covers an area of several acres, the dip of the beds is uniformly toward the east:

Section in Haas's gravel pit, near Oak Park, Illinois.

	Inches.
Brown stained gravel capping summit and slope	18–30
Fine gravel, fresh or stained but little	24–48
Sand, very thin at top, but increasing toward side of ridge	0–36
Fine gravel, increasing toward side of ridge	0–48
Fine gravel, which passes upward from near the east side of the excavation, assuming a nearly horizontal position beneath the crest of the ridge	40–48
Sand, thickening toward the higher part of the ridge	6–36

Another gravel pit has been opened in the beach between Salt Creek and Lagrange, in which the excavation extends from the east side of the beach westward nearly to the outer slope. It has a depth of 12 to 14 feet, and exposes a series of beds dipping slightly toward the east. The upper 5 feet is of brown stained gravel; the lower portion is a fine gravel with very little stain. In the gravel there are sandy pockets and also thin beds of sand. These sandy portions in some cases show a slight effervescence with acid, but are not nearly so calcareous as sand found at similar depth in glacial deposits.

At Dyer, Indiana, the beach is crossed by a small stream, which exposes the following section:

Section of beach in bank of stream at Dyer, Indiana.

	Feet.
Sand	6
Sandy gravel	6
Bluish sandy gravel, with water	3–4
Yellowish-gray clay	6
Total	22

At Schererville the sand has a depth of about 25 feet on the crest of the ridge, but only 12 to 15 feet at the inner border, and thins out to about 8 feet a half mile north of the crest.

South of Michigan City the gravel in the beach is shown by wells to have a depth of about 12 feet and rises 6 or 8 feet above the bordering marsh on the south. This appears to be somewhat more than the usual depth of gravel along this portion of the lake border.

At the point where the gravel ridge comes to the lake shore north of New Buffalo, Michigan, the gravel is 10 or 12 feet in depth. Sections of two wells in sec. 36, located on this ridge, also show about 12 feet of gravel and sand. In one well a bluish clay is interbedded with the lower portion of the gravel. In another the gravel is underlaid by 2 or 3 feet of sand, and this deposit rests on the till.

A well on the beach west of Sawyer penetrated 6 feet of sand, beneath which was a water-bearing gravel, which, at a depth of 6 feet, furnishes sufficient water to supply several families.

In the sand ridge at Overisel, in northern Allegan County, wells often pass through a bed of brush and herbaceous vegetation at the bottom of the sand, a feature which indicates that the sand has encroached upon a land surface at that point, and supports the view, above suggested, that it has been drifted by wind slightly above the general level of the old water surface.

Remains of animal life have been reported only at a few points along the entire length of the portion of the beach examined, and none have been observed by the writer. Mr. Haas reports that shells of the size of Unios, and also smaller molluscan shells, have been found in a bed of sand at the bottom of the gravel pit which he has opened near Oak Park. Upon the request that he preserve any shells which might subsequently be found, he

responded within a few weeks by sending a shell which proved to be the ordinary oyster. Since the beach marks the border of a lake which stood sufficiently above sea level to maintain a strong current through its outlet, it seems highly improbable that the lake was occupied by marine life at this time. Upon revisiting the gravel pit and inquiring particularly into the circumstances, it was found that the shell was picked up by some of the workmen near the base of the pit. But it was also found that there are a few Indian graves which extend down nearly to the level of the base of the pit. The shell, therefore, may have been introduced at the time these graves were made, or may have been of more recent introduction. Remains of terrestrial life have also been found in this gravel pit. Mr. Haas has preserved fragments of the tooth of a mammoth found at the depth of several feet. These fragments are waterworn, and it seems, therefore, quite probable that they were embedded during the formation of the beach

Another locality in which supposed Unio shells have been reported is found in a marsh on the inner side of the beach north of New Buffalo, Michigan. Mr. Glavin, formerly county surveyor of Berrien County, reports having observed shells as large as the ordinary clam shell in ditching near the borders of this marsh. He has, however, preserved none of the shells, and possibly may be mistaken in his identification. So far as known to the writer, these are the only places along the entire length of the upper beach where molluscan shells have been reported, and none have been personally found, though search has been made for them in several exposures and excavations. There appears, therefore, to have been a great scarcity of molluscan life in this stage of Lake Chicago.

INTERVAL OF EMERGENCE.

After the Glenwood beach was formed, the lake appears to have withdrawn from the plain in Illinois lying between the beach and the shore of Lake Michigan. To what extent it withdrew within the present limits of the lake is not accurately determined. The evidence for this emergence near Chicago is found in beds of peaty material that occur beneath gravel of the succeeding lake stage, as long since noted by Dr. Andrews and discussed in his paper cited above. Similar peaty material underlies beach gravel near Michigan City, Indiana. In Wisconsin, clay beds which seem to have been left in a retiring water body, and which are covered by beach

deposits of the succeeding lake stage, are referred by Chamberlin to the same category.[1]

Along the east shore of Lake Michigan evidence of emergence is found in deep channels along the lower courses of the streams tributary to the lake—channels which are in some cases excavated in the till and therefore of later date than the last ice invasion. Attention was called to these channels many years ago by Dr. Alexander Winchell.[2] They were subsequently discussed by Dr. C. W. Wooldridge.[3] The latter made a special study of the lower course of White River, known as White Lake, and also made a reconnaissance from Grand Traverse Bay to the mouth of Grand River. He made the important discovery that the beds of several of these streams "are excavated in the drift clay and not in the surface sand which overspreads the lower levels in their vicinity." On the borders of White Lake the sand is usually only a thin deposit 1 to 4 feet in depth and the clay surface reaches a height of 15 to 30 feet above the level of the lake. Similar features are found on Duck Lake, Pentwater Lake, and Manistee Lake. The latter observation carries the emergence well into the northern half of the Lake Michigan Basin.

The depth to which the erosion extended is difficult to determine, since these channels have no doubt been filled to some extent during the subsequent emergence. Dr. Wooldridge found a point near the mouth of White Lake in which there is 84 feet (14 fathoms) of water. The U. S. Lake Survey charts show a depth of several fathoms in each of the tributaries of Lake Michigan from Pere Marquette Lake southward to the Kalamazoo River, as follows:

Depths of lakes tributary to Lake Michigan.

	Fathoms.
Pere Marquette Lake	7
Pentwater Lake	8
White Lake	10
Muskegon Lake	9
Spring Lake	7
Black Lake	5
Kalamazoo River[4]	16?

The above soundings demand an emergence of at least 50 feet above the present shore, even if the bottoms are but slightly filled, and it seems

[1] Wisconsin Geological Survey, Vol. II, pp. 221–224, 229, 230.
[2] Harper's Magazine, July, 1871, p. 284.
[3] Amer. Geologist, Vol. I, March, 1888, pp. 143–146.
[4] Possibly the soundings at mouth of Kalamazoo River represent feet instead of fathoms.

not improbable that the amount of filling is such as to necessitate the assumption of an even greater emergence in that region.

The simplest conception of the lake history would postulate only one period of emergence, but the available data suggest greater complication. It remains to be determined whether the deep channeling may not pertain to a later interval of emergence in which there was greater uplift than in the interval under consideration. Observations made by the writer in the vicinity of Holland, Michigan, lead to the view that the channeling occurred subsequent to the formation of the strong beach which stands 60 to 65 feet above Lake Michigan, and prior to the formation of a beach which stands about 25 feet above the lake. If the 60-foot beach proves to be a continuation of the Calumet or Second beach of Lake Chicago, this emergence would seem to have occurred between the formation of the Second and Third beaches; but if it represents the Glenwood beach, the emergence may have been in the interval under discussion. This would throw it into the same category with the peaty deposits noted near the south end of the lake. The lake charts indicate that the lower courses of tributaries on the west side of Lake Michigan are not characterized by the deep channels which are common on the east side of the lake. This may be attributable in part to their being in a more elevated part of the lake border, in which channeling was so narrow that it has been completely filled. The absence of deep channels at the south end of the lake may be due to obliteration by sand accumulations. It seems very doubtful if one shore suffered much greater uplift than the other. Further light is necessary to a satisfactory interpretation of the evidence of a low lake level. The relation of the Third beach to these deep river channels on the east side of Lake Michigan is set forth on a later page, as are also evidences favoring the view that channeling occurred subsequent to the formation of the Second beach.

THE SECOND OR CALUMET BEACH.

This beach throughout much of its course in Indiana follows the south border of Calumet River, and because of this close association the name Calumet seems appropriate. From Chicago around to St. Joseph, Michigan, it stands about 20 feet lower than the upper beach, but it may be separated somewhat more widely from that beach farther north. An interval of about 35 feet is found between the upper limits of wave action east of Holland,

Michigan, and the strong beach which occurs at 60 to 65 feet above the lake. Tracing somewhat in detail, its course is as follows:

From the Wisconsin line southward to Chicago River, just above the city of Chicago, it is closely associated with the upper beach, so that where one beach is cut away by the lake the other is also. The Second beach flanks the inner border of the upper beach in Niles Township. From the Chicago River to the Des Plaines the Second beach is separated from the upper beach by an interval of 1½ to 3 miles and passes somewhat directly from Jefferson Park through Austin to Riverside. The head of the outlet of Lake Chicago at this stage was at a line connecting the villages of Riverside and Summit. The beach gravels are well developed for a short distance below Summit on the east side of the outlet, while the west side is marked by a cut bank of corresponding elevation. The beach proper leads somewhat directly southeastward from Summit to the north end of Blue Island Ridge and then southward along the east side of the ridge, past Washington Heights, coming to the Calumet River 2 or 3 miles east of Blue Island. The Sag outlet had its head at this time in a wide opening between the Calumet River and Thornton. Immediately east of Thornton the beach appears in its customary strength and passes thence eastward into Indiana.

Upon entering Indiana the beach follows the south border of Calumet River across Lake County and western Porter County to the point where the upper beach, as noted above, passes to the north side of the river. It is closely associated with the upper beach from near the village of Ross, Indiana, eastward. It is also closely associated with it for several miles east from the point where it crosses the Calumet River, but in the vicinity of Furness the two beaches become separated by a nearly level swampy tract, about one-half mile in width, and continue distinct to Trail Creek, just east of Michigan City. The Second beach passes through the south part of that city.

Upon passing into Michigan, this beach becomes so greatly obscured by the belt of dunes formed along the border of the lake that exposures are found only at a few points. In several places in Berrien and Van Buren counties it was recognized and found to have an altitude 35 or 40 feet above Lake Michigan. The exposures in every case are along the bluff of the lake. As already indicated, the writer has had opportunity to make only a hurried reconnaissance of the lake border northward from Van Buren

County, and can not therefore speak with certainty concerning the continuation of the beach. The beach, which on the whole seems to be the most natural continuation, stands 60 to 65 feet above the lake on a line examined eastward from Holland. Its relation to the other beaches is similar to that found farther south, there being one beach between it and the present beach of Lake Michigan, and another beach or similar evidence of wave action at a level above that of this beach. The character of the wave action and shore markings of the upper level have already been noted.

An important bar was formed at this stage of the lake just north of Chicago. Its northern end appears at the bluff of the lake between Wilmette and Evanston, and leads thence southward through the west part of Evanston to Rose Hill Cemetery, where it turns abruptly westward and terminates in Bowmanville, on the east bluff of Chicago River. It is probable that this bar was attached to the old shore at some point farther north than its present terminus, a portion of it having been removed by the encroachments of Lake Michigan. The bay back of this bar had a width of 1 to 4 miles and a depth of 15 to 20 feet in its deepest part. A large portion of it was so shallow as probably to be marshy. Notwithstanding the presence of this bar, the beach back of it appears to have been acted upon by lake waves with nearly as much vigor as the portion of the beach farther south, a feature which suggests the absence of the bar in the early stages of this lake level. The bar is much more bulky than any part of the beach proper, being 10 to 20 feet in height and nearly one-fourth mile in average breadth, if the sand and gravel on its borders are included.

The Second beach is on the whole characterized by larger deposits of gravel and sand than the upper, but it has less conspicuous cut banks. Its strength is greater in the vicinity of the northern outlet and on the north side of the southern outlet than at points either between or outside the outlets. In Indiana and Michigan, however, it is quite large, but is heavily covered with sand, which is largely wind-drifted. In places these accumulations of sand reach a height of 30 or 40 feet.

In respect to the remains of life, this beach is similar to the upper beach. Very few reports of the occurrence of shells were received, and no shells were found in the beach by the writer. It is in striking contrast with the next lower beach, which is in places highly fossiliferous.

An excellent exposure of the structure of the bar noted above is found immediately north of Evanston, where the lake is undermining the bar as well as subjacent deposits. The gravel and sand forming the bar rest upon a bed of peat, which was long since noted by Dr. Edmund Andrews and interpreted by him to be the accumulation of a marsh or partially submerged land surface.[1] The peat not only underlies this bar, but extends eastward across the interval between it and the Third beach. Its level is no higher than that of the Third beach, being only 12 to 15 feet above the present level of Lake Michigan. The peat is in places several feet thick, but at the point where the bar comes out to the lake shore it has a thickness of only a few inches. It there contains pieces of wood which show evidence of disturbance by waves. Between the peat and the yellowish blue till that forms the base of the exposure there is a gravelly sand 6 to 18 inches in thickness which appears to be a lacustrine deposit. The peat is immediately overlaid by about 5 feet of sand, above which there is a bed of coarse gravel. The gravel is thin near the borders of the bar, but has a thickness of 10 or 12 feet at the highest part. It is capped by a thin deposit of sand, and has also layers of sand interbedded in its thickest part. The presence of this gravel makes it certain that the old marshy land surface has not been buried by the drifting of material from the lower beach. There seems no escape from the conclusion that the lake stood at a lower stage than the level of the Second beach before that beach and the bar under discussion were formed.

For a few miles in the vicinity of the State line of Indiana and Michigan there are exposures of peaty material along the bluff of Lake Michigan at levels ranging from about 15 feet above the lake down to the water's edge. The peaty layers are seldom more than 6 inches thick and are interbedded with sand. One layer standing 12 to 15 feet above the lake appears $1\frac{1}{2}$ to 2 miles southwest of New Buffalo and is traceable continuously for fully one-half mile. Near Michigan City peaty layers just above the water's edge are nearly continuous for a distance of a mile or more, and occur at frequent intervals from Michigan City to the Michigan State line. Above the peaty beds pebbly sand in places reaches an elevation of 30 feet above the lake, or nearly to the level of the Second beach. The peat appears, therefore, to

[1] Trans. Chicago Acad. Sci., Vol. II, 1870.

have been developed prior to the formation of that beach, and probably has the same age as that noted near Evanston, Illinois.

POSSIBLE SECOND EMERGENCE.

As indicated above, features near Holland, Michigan, apparently call for an interval of emergence there between the formation of beaches which stand second and third in the series of that region. Immediately south and east of Holland a beach is built up from the level of the plain on which Holland stands, which is 30 to 40 feet above Lake Michigan, to an elevation 60 to 65 feet above the lake. It consists of sandy gravel, becoming in places nearly clear sand. In connection with this deposit there is a sandy gravel which extends 2 miles or more up the Black River Valley, and has the appearance of being a delta accumulation formed by a larger stream than the present river. A broad abandoned channel nearly a mile in width leads from Grand River just below Grand Rapids southwestward to the Black River Valley at Holland, which has opened a broad passage through this delta, or rather a double channel, with an island-like remnant of the old delta south of Zeeland. The amount of erosion would be great if it had extended only to the level of the marsh; but judging from the depth of the channel of Black River from Holland westward to Lake Michigan, which, as shown above, reaches a level 30 feet below the lake, the marsh has been greatly filled during the formation of a lower beach which crosses Black River at Holland. The filling can not well be less than 50 feet. This depth of excavation not only increases the work done but indicates that there was sufficient emergence above the level of the present shore of Lake Michigan to cause stream channeling to extend 30 feet or more below lake level. The relation of the lower beach to the head of the lake-like expansion of Black River is discussed in connection with the Third or Tolleston beach.

Deep channeling on the lower course of other eastern tributaries of Lake Michigan, above noted, appears to have occurred contemporaneously with that of Black River. What relation this channeling may have to the Algonquin and Nipissing lake stages is yet to be determined. During each of these lake stages the water in the south part of the Lake Michigan Basin is thought by those who have studied their beaches to have been below the present level of Lake Michigan. But it is also thought that in the northern

part of the basin these lakes extended beyond the present shore. As the deep channeling of the valleys is continued well into the north half of the basin, it may prove to be independent of the supposed Algonquin and Nipissing lake levels in that region.

THE THIRD OR TOLLESTON BEACH

This beach received its name from the village of Tolleston, situated in northwestern Indiana at the crossing of the Pittsburg, Fort Wayne and Chicago and the Michigan Central railways, at a point immediately south of the extreme head of Lake Michigan, and distant only 2½ miles from the head of the lake. It is more complex than either of the higher beaches. Indeed, it is a matter of no small difficulty to determine what beachlets should be included with this lake stage. There are, by actual count, 32 beachlets crossed on a north-south line about 3 miles east of the State line of Illinois and Indiana. The outer line of this series is usually much stronger than the others and stands a few feet higher, and hence is considered the main line. The village of Tolleston and also Hessville and Miller Station, in Indiana, are situated on the outermost or main line.

Many of the beachlets situated between the main line and the shore of Lake Michigan stand only 10 to 12 feet above that lake, and, as shown farther on, seem to have been formed after the southwestward outlet was abandoned. This being the case, they may not be referable to Lake Chicago. The Third or Tolleston beach, as here described, includes only such beaches and bars as have sufficient elevation above the sill of the Chicago Outlet to indicate that they are connected with that outlet—beaches whose elevation is 18 to 25 feet above the level of Lake Michigan.

The portion of the shore of this lake stage in Lake County, Illinois, is closely associated with that of the higher lake stages and consists of a gravelly deposit flanking the foot of the old lake bluff. In Cook County this beach appears at the lake bluff on the grounds of the Northwestern University, in Evanston, and for several miles south it lies near the east border of the bar formed at the next preceding lake stage. From Rose Hill Cemetery southward it is beyond the limits of the bar, but is perhaps itself a bar built out southward into a bay now traversed by Chicago River. It appears to have reached some distance south at an early part of this lake stage, for only a poorly defined beach appears on the west side of

the bay back of it. Mr. W. C. Alden has found slight traces of the beach in the west part of Chicago.[1] This bar lies within a mile of the present shore of Lake Michigan and is readily traced as far south as Lincoln Park. The bar is said to have been nearly continuous through the city of Chicago, but in grading up the business portion of the city it has been obliterated from Lincoln Park southward nearly to the Douglas Monument, and the writer has been unable to obtain a map or other accurate data showing its former extent. The bar is preserved from the Douglas Monument southward to Englewood, a distance of 4 or 5 miles. This portion consists of a series of overlapping ridges, of which the westernmost or earlier terminate farther north than their successors on the east. At the termination of each of these ridges a hook turns out to the west into the bay that stood west of the bar. An outlet seems to have been maintained toward the Des Plaines around the southern end of this advancing bar, until it reached Englewood. This may not have been closed until the water level had dropped too low for a discharge to the Des Plaines. It formed a well-defined gravelly shore in its north border from the Hawthorn quarry westward to Riverside, as determined by Mr. Alden. Upon passing across the outlet marsh from Englewood to South Lynne one finds a continuation of the Tolleston beach, which leads northwestward to the Des Plaines at Summit. From South Lynne it leads in a course east of south to South Englewood and thence more nearly east across the northwest corner of Calumet Township into Hyde Park, coming to the Illinois Central Railway a short distance north of Pullman. From this point a gravelly ridge is traceable southward past the north border of Lake Calumet, where it dies out in the marsh. A slight beach is formed to the northeast from here on Stony Island, between Lake Calumet and South Chicago. But the main line of this beach is found west of Lake Calumet, running north and south through the west parts of Pullman and Kensington, where it usually has the form of a cut bank 10 to 15 feet in height, but changes to a gravelly and sandy beach at the south. This beach comes to the Calumet River at Riverdale, where it connects with the Sag outlet. It reappears on the south side of the river at Dolton and passes thence southeastward into Indiana.

[1] Mr. Alden has made a thorough mapping of the surface deposits of the Chicago and Calumet quadrangles for this Survey.

Its course in Lake County, Indiana, is eastward through Hessville and Tolleston and Miller. Farther east it becomes lost beneath the dunes that border Lake Michigan. From the vicinity of Michigan City, Indiana, northward through Berrien, Van Buren, and Allegan counties, Michigan, it has been extensively removed by Lake Michigan, for the lake bluff usually rises above its level and presents deposits as old as the Second beach.

The first appearance of a low beach of any notable extent in Michigan is that found in the vicinity of the line of Allegan and Ottawa counties, south of the lake-like expansion of Black River. This beach leads from the shore of Lake Michigan eastward to Holland, Michigan, and there takes a northward course, crossing Black River at the head of its lake-like expansion. It stands about 25 feet above Lake Michigan, except where sand dunes have given it greater height. Along Black River Valley above this beach there is a gravel filling, apparently a later delta than that described above, built up to about 25 feet above Lake Michigan, at the point where the beach crosses, but rising to fully 30 feet near Zeeland, 3 miles east. At the head of this delta there is a marshy valley with a width of a half mile or more, which connects at the northeast with the valley of Grand River, as indicated above. The bottom of this marshy valley at the present divide, near Hudsonville, as shown by the Chicago and West Michigan Railway survey, stands about 45 feet above Lake Michigan, thus allowing only 15 feet fall from Hudsonville to Zeeland, a distance of fully 12 miles. Below the point where this beach crosses Black River there is, as above stated, a channel which extends 30 feet or more below Lake Michigan. It is a half mile to 1 mile in width, being as broad as the gravel-filled valley above. From the gravel filling to the bottom of this channel there is a descent of 50 or 60 feet in less than 2 miles. It is probable, therefore, that, at the point where the beach crosses, the filling reaches at least 50 feet. The cause for the abrupt termination of the deep part of the lower course of Black River appears, therefore, to be due to the covering of this part by lake water while the beach and delta were forming at the edge of the lake. It seems probable that the abrupt termination of the deep part of tributaries of Lake Michigan north from this one is due to a similar relation to a beach, but this is merely an inference, as that region has not been visited by the writer. Much remains to be

determined concerning the development of channels in this region and their modification during the high lake stage or stages.

The portion of this beach in Illinois consists mainly of fine gravel, which is usually well worn, but in places has considerable angular material, as if formed rapidly and subjected for but a brief period to the action of the lake waves. The low district along the Chicago River back of this beach has received quite generally a coating of sand several feet in depth, and the marshy tracts in Hyde Park and Lake townships are also covered with sand to a depth of several feet. Excavations have shown, however, that till usually sets in at a depth of 10 to 20 feet or less. (Alden.)

In Indiana this beach, like the present shore of Lake Michigan, is very sandy. Its dunes, however, seldom reach a greater height than 50 feet, or but one-third to one-quarter the height of dunes on the present shore. Wells along it have occasionally encountered a bed of gravel at the base of the sand at levels corresponding with the gravelly beaches of the Illinois portion.

One of the best exposures of this beach is found at the border of the campus of the Northwestern University, at Evanston, Illinois. The following sections, one taken by Dr. Oliver Marcy, in 1864, at which time there was a peculiarly good exposure, the other taken by the writer in 1887, at which time there was a less extensive exposure, show a slightly different section. The beach in this interval had suffered an erosion of perhaps 75 or 100 feet.

Section of beach at Evanston made in 1864.

	Feet.
Surface soil, sandy	1½
Brown sand and fine gravel	2½
Coarser gravel, stratified	2½
Fine sand	2
Gravel, containing bones of deer	1½
Fine sand, containing oak logs	1½
Peat or carbonaceous earth with a marl bed containing molluscan shells in the lower portion, or interstratified with the peat	1½
Gravel	3½
Humus soil, with stumps and logs (coniferous)	½
Yellow clay, laminated and contorted, containing pockets of gravel	3½
Blue, pebbly clay	2
Height of bluff	22

Section of beach at Evanston made in 1887.

	Feet.	In.
Yellowish-red, iron-stained sand	3 – 5	
Band of bog iron ore		4– 6
Gravel with beds of sand included (the stratification is very irregular in thickness and assorting very imperfect)	5 – 7	
Coarse sand, not calcareous		6–12
Calcareous loam		3
Yellow clay, very calcareous, with leaves embedded		3
Carbonaceous band, not calcareous		2
Yellow carbonaceous clay, calcareous		4– 6
Band of carbonaceous material, not calcareous		2
Brown sand, with twigs and peaty material		8–10
Water-bearing sand and talus-covered slop	8	
Height of bluff	22	0

The calcareous clays of each section contain numerous gasteropod shells. Dr. Marcy has collected a large number of shells from them, among which there are Unios, apparently of several different species but not specifically identified. Mr. C. T. Simpson has identified nine different genera of mollusks, all of existing species, found in the peat and marl bed of Dr. Marcy's section. Planorbis and Lymnæa are very abundant. Prof. D. P. Penhallow has identified two wood specimens, one a new species of Picea (*Picea evanstoni*), the other a new oak (*Quercus marcyana*).[1] The bone of the deer found by Dr. Marcy is a portion of the femur. The writer has found many localities in the sandy portions of this beach, where molluscan shells abound. Nearly every exposure in the sandy district west of the beach, from the main part of the city of Chicago southward to Englewood, exhibits them. This beach is, therefore, in striking contrast with the two higher beaches, which contain few shells or other remnants of life.

An excellent artificial section across this beach, made by the Fullerton avenue conduit, which leads from the Chicago River eastward to Lake Michigan, across the north part of Chicago, is discussed above. The deposit throughout is mainly sand, but some gravel was encountered. Shells of Unios and other mollusks were noted at frequent intervals throughout nearly the whole width of the deposit. Beneath these beach deposits there is everywhere a pebbly blue clay, apparently an unmodified glacial till. Some of the sewer ditches in Hyde Park, west of Grand Boulevard, have reached peat deposits below sand, at a level a few feet above the lake. Wood has often been found in the sand west of this beach in Chicago.

[1] Trans. Royal Soc. Canada, 1891, pp. 29–32, Pl. II.

Reference has been made to the beachlets which occupy the interval between the main beach and the present shore of the lake. These do not form continuous lines around the head of the lake, but those in the vicinity of the Chicago University and Jackson Park die out in a marsh which sets in a short distance south of the park, and those in Lake County, Indiana, die out at their western ends in a sandy plain which borders Wolf Lake, Lake Calumet, and other small lakes near the State line. This sandy plain stands but 5 to 8 feet above the lake, and was apparently an open bay at the time these bar-like features were forming. But it has now become filled with sand, leaving Lake Calumet and the other small lakes as its dwarfed representatives. The beachlets stand only 10 to 12 feet above lake level (except where coated by wind-drifted sand), and, as noted above, seem referable to the action of the present lake rather than to Lake Chicago.

The outlets of the lake at the time the Third beach was forming appear to have been along three lines—the first, that occupied by the mouth of the Chicago River and the south branch of the Chicago River (reversed); a second along the marsh referred to above as leading from the south part of Hyde Park Township northwestward between Englewood and South Lynne, which connects with the south fork of the Chicago River north of the Union Stock Yards; a third leading westward from Riverdale along the Sag outlet. The broadest of these outlets is that leading past Englewood and the Union Stock Yards, and it is possible that the other outlets became nearly closed by sand before this outlet was abandoned.

The altitude of this beach in Illinois and Indiana is nowhere more than 20 to 22 feet above the lake, except where wind has drifted sand to higher levels. The outlet could not well have been cut below a level 8 feet above the lake, that being the altitude of the Chicago Outlet for several miles below its junction with the present Des Plaines River. The depth of the water in the outlets would, therefore, be 10 to 12 feet or less. As beaches are often built up to a height of 4 or 5 feet above the ordinary level of the lake, it seems probable that the ordinary stage of water was not more than 15 feet above the present stage of Lake Michigan, thus leaving but 7 feet depth of water in the outlet. The Sag outlet reaches nearly 15 feet above the level of Lake Michigan; hence it was probably only a minor line of discharge.

As hinted above, the reference of this beach to the same lake which formed the higher beaches is not made with any degree of confidence.

Indeed, the abundant life of the waters which formed this beach distinguishes it so strikingly from the paucity of life which characterizes the other beaches that a suspicion of a different origin at once arises.

Dr. J. W. Spencer has advanced the view that an uplift at the Niagara outlet is still in progress, and has suggested that the recession of the falls of Niagara past Johnson's Ridge, a ridge standing higher than the remainder of the gorge and situated about a mile north of the falls, would have caused a temporary partial discharge of the upper lakes, including Lake Erie, into the Mississippi, a discharge which did not stop the outflow by Niagara. He maintains that when Niagara Falls had effected the incision through Johnson's Ridge, the level of Lake Erie fell about 24 feet, reaching a level 17 feet below the Chicago divide, and thus the full flow of the outlet was returned to Niagara.[1]

The test of the value of Dr. Spencer's ingenious suggestion lies in the occurrence of phenomena immediately south of Johnson's Ridge, which will demonstrate that the water stood at a level sufficiently high to have caused outflow from the Chicago Outlet. Such a stage of water should have left shore markings there as well as on the plain at the head of Lake Michigan. The view that an uplift is still in progress in the vicinity of the Niagara outlet is apparently sustained by recent evidence brought out by Mr. G. K. Gilbert.[2] The question of the date of this beach and of its relation to uplifts and barriers ought, however, to be left open until more complete evidence is gathered.

THE PRESENT BEACH OF LAKE MICHIGAN.

Dr. Edmund Andrews some years ago discussed the present beach of Lake Michigan and compared its strength with that of the beaches of Lake Chicago.[3] Since his paper is now out of print and copies of it are difficult to obtain, some of the computations there made are presented below. Dr. Andrews apparently includes the beachlets between the Tolleston beach and the shore of Lake Michigan, referred to above, in the present lake stage.

The lake is generally encroaching upon the district on its west border from the Wisconsin line southward to Chicago, though piers built along the shore in Chicago, and for some distance northward, now prevent further

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[1] Proc. Am. Assoc. Adv. Sci., Brooklyn meeting, 1894, pp. 242, 243.

[2] Nat. Geog. Mag., Sept., 1897, pp. 233–247. A fuller discussion has been presented by Gilbert in the Eighteenth Annual Report of this Survey, Part II, pp. 595–647, issued in 1898.

[3] Trans. Chicago Acad. Sci., Vol. II, 1870, pp. 1–23.

encroachment. Along the borders of Hyde Park, in the south part of Chicago, the lake is building a beach and is tending to fill in rather than to extend the lake in that region. In Indiana the lake is filling in rather than extending its borders. In southwestern Michigan it is eroding the prominent parts more rapidly than the bights, thus giving the lake a more regular outline. In this connection it may be remarked that the tendency generally is to remove the prominent parts and fill the bights.

Dr. Andrews computed the bulk of the beach as follows: For 25 miles west from Michigan City it maintains an average cross section of about 6,000 square yards, and its contents are 264,000,000 cubic yards. In this division the beach is in the form of a lofty belt of sand dunes, about one-third of a mile wide and in places nearly 200 feet in height. In the next 8 miles west the beach spreads out into a broad belt of low parallel ridges about two miles in extreme width. This division has a cross section of about 16,000 square yards, after deducting the sand which was deposited by Lake Chicago. Its contents amount to 225,280,000 cubic yards. From the Indiana line, near Wolf Lake, to Chicago River, a distance of 16 miles, the sand occupies a belt estimated to be 7 yards thick on the shore but running out to a thin edge at the average distance of 2,500 yards inland. It therefore has a cross section of 8,750 square yards and contains 246,400,000 cubic yards. To this should be added the portion of the beach under water. This, taken for the entire distance from Chicago to Michigan City, is estimated to be about 1,011,890,000 cubic yards. The computation of the subaqueous belt is as follows: The sand at the shore line is about 10 feet deep, and it extends out to where the water reaches a depth of 24 to 36 feet. The breadth varies greatly, ranging from about 1,000 yards to nearly 5 miles, the widest part being at the head of the lake. The total bulk of the lake deposits, both in and out of the water, in the section between Michigan City and the mouth of Chicago River, is estimated to be 1,747,570,000 cubic yards, or about one-third of a cubic mile.

Dr. Andrews estimates that the combined bulk of the beaches formed by Lake Chicago is nearly equal to that of the beach of the present lake, the proportion being 16 to 17. In this computation it was assumed that 656,000,000 cubic yards, or nearly one-eighth of a cubic mile, escaped through the Chicago Outlet. This assumption is based on a comparison of the relative sizes of the beaches of Lake Chicago in a section outside the outlet and a section embracing the outlet.

Dr. Andrews attempted to estimate the length of time involved in the accumulation of the beach deposits by measuring the amount of sand carried southward past the piers at Chicago and Michigan City. The sand annually stopped by the two piers was found to be 129,000 cubic yards. If this represented the whole drift past the piers, the period required for the accumulation of the sand in all the beaches would be about 26,000 years and the duration of Lake Michigan at its present stage would be 13,000 years. He estimates, however, that not more than one-fourth or one-fifth of the southward-drifting sand is stopped by the piers, and thus reduces the period to less than 6,000 years, with but about 3,000 years for Lake Michigan.

Dr. Andrews's estimates were based on the assumption that there is a southward-flowing current on each side of the lake, carrying sand to its present head. Investigations made by the Weather Bureau in 1892 and 1893, under the direction of Prof. Mark Harrington,[1] led him to the conclusion that the currents on the east shore in the southern portion of the basin are northward instead of southward. He accounts for the accumulation of sand on the north side of breakwaters along this coast by the action of the surf, in storms blowing from the north, which is more transient than the currents proper and would affect the southern part of Lake Michigan only when the wind was in the north. This occasional phenomenon is very efficient when it occurs. He concludes that the estimates of time involved in the formation of beaches have less value than they would have if the accumulation were due more largely to lake currents.

Considerable study of the movement of water in Lake Michigan has been made by the Chicago Drainage Commission, largely under the direction of Professor Cooley. As a result of these investigations, which involve not only a study of bottle papers, but also a thorough canvass of the opinions of lake captains and an examination of breakwaters, Cooley has reached the conclusion that the effective work on the shores is due to waves and not to currents, and it is a matter of doubt if this lake has such a system of currents as are indicated by Professor Harrington's charts. The movement of the water seems to depend mainly upon the wind, but is governed to some degree by the contours of the shores. If the north winds prevail for a few days, as is often the case in the spring months, the surface water appears to have a southward movement throughout the

[1] Currents of the Great Lakes as deduced from the movement of bottle papers during the seasons of 1892 and 1893, by Mark W. Harrington: Weather Bureau Bulletin B, U. S. Dept. of Agriculture, 1894.

breadth of the lake, and return currents must be at some depth. On the other hand, a prevailing south wind, such as occurs for short periods during the summer, will induce a northward movement across the entire breadth of the lake. The contours of the shore seem to favor a northward movement from direct west winds in the north half and a southward movement in the south half of the lake. As the prevailing winds are often from the west, these become the most protracted of the movements of surface water. Cooley has found that breakwaters along the shore support this interpretation. In the southern half of the lake they are largely constructed to protect the harbors from the drift on the north side, while in the northern half they are constructed to protect them from drift coming from the south. In view of this apparently changeable course of lake movements, it seems doubtful if estimates, such as Dr. Andrews attempted, have the value that some have attached to them.

Dr. Andrews also made an estimate of the age of the lake from the annual amount of destruction of the bluffs. To determine the rate of erosion on the west coast of Lake Michigan, he gathered a large number of observations, mostly derived from surveys, and after rejecting loose or vague estimates, as well as erosions brought to notice because of remarkable rapidity, he obtained the results given in the following table:

Erosion of the shore of Lake Michigan per annum.

	Feet.
Evanston	16.95
Old pier, 2 miles farther north	4.90
One mile farther north	3.08
Winnetka	4.05
One mile farther north	6.05
Lake Forest	1.65
Waukegan	0.00
Two miles farther north	0.00
State line	16.50
Kenosha	12.00
Two miles farther north	3.00
Three miles farther north	12.00
Racine Point	16.00
Racine	6.00
Oak Creek	2.00
One mile farther north	1.60
Milwaukee	6.25
Port Washington	2.30
One mile farther north	1.50
Place farther north	3.00
Place 4 miles south of Sheboygan	8.00
Sheboygan	6.25
Manitowoc	5.00

From the above table it appears that the average erosion in the portion of the shore between Milwaukee and Manitowoc is 4.33 feet a year, while between Milwaukee and Evanston it is 6.24 feet a year. The average erosion of the two sections is 5.28 feet.

A series of more careful measurements than those given in the above table appears in the Geology of Wisconsin and covers part of this section of the shore. The following is the statement furnished by Dr. Lapham to Professor Chamberlin:[1]

Mr. S. G. Knight, of Racine, has carefully measured for the Geological Survey the distance from the nearest section corner or quarter post to the bank of Lake Michigan along all the section lines in Racine County, the results of which, compared with the Government survey made in 1836, are given in the following table. Had these measurements been made at right angles to the shore line, the result would have been a trifle less; but as some portions of the bank have been artificially protected, we may assume the result as a close approximation to the actual amount of loss during the past thirty-eight years in Racine County. These measurements will have their value many years hence.

Erosion of the lake shore in Racine County, Wisconsin.

Section lines.	1836.	1874.	Loss.
	Chains.	*Chains.*	*Chains.*
North line, sec. 6, T. 4, R. 23	32.70	30.30	2.40
North line, sec. 7, T. 4, R. 23	34.68	33.45	1.23
West line, sec. 8, T. 4, R. 23	30.18	29.70	0.48
North line, sec. 17, T. 4, R. 23	16.38	14.60	1.78
West line, sec. 16, T. 4, R. 23	10.86	9.75	1.11
North line, sec. 21, T. 4, R. 23	15.58	14.50	1.08
West line, sec. 22, T. 4, R. 23	19.39	18.43	0.96
North line, sec. 27, T. 4, R. 23	26.39	26.39	0.00
North line, sec. 34, T. 4, R. 23	16.04	15.47	0.57
West line, sec. 34, T. 4, R. 23	31.50	30.00	1.50
North line, sec. 4, T. 3, R. 23	28.03	26.50	1.53
North line, sec. 9, T. 3, R. 23	18.82	18.00	0.82
North line, sec. 16, T. 3, R. 23	27.80	20.60	6.20
North line, sec. 21, T. 3, R. 23	21.25	18.00	3.25
North line, sec. 28, T. 3, R. 23	32.22	31.16	1.66
West line, sec. 28, T. 3, R. 23	30.20	23.87	6.33
North line, sec. 32, T. 3, R. 23	34.85	32.40	2.45
South line, sec. 32, T. 3, R. 23	46.60	44.73	1.87
Mean of eighteen places			1.92
Same in feet, 126.72.			
Loss per annum in feet, 3.33.			

[1] Geology of Wisconsin, Vol. II, 1877, pp. 231, 232.

The following measurements were made to ascertain the amount of the abrasion of the west shore of Lake Michigan, in Milwaukee County, since the Government survey, made in 1835 and 1836:

Place.	1835.	1874.	Annual loss.
	Chains.	*Chains.*	*Feet.*
South line, sec. 1, T. 5, R. 22	45.61	44.50	1.9
South line, sec. 36, T. 6, R. 22	15.90	14.40	2.6
South line, sec. 24, T. 6, R. 22	19.29	18.70	1.0
South line, sec. 21, T. 7, R. 22	8.72	8.42	0.5
South line, sec. 15, T. 7, R. 22	5.37	2.82	4.32
South line, sec. 10, T. 7, R. 22	43.35	41.64	2.9
South line, sec. 3, T. 7, R. 22	19.34	17.36	3.33
South line, sec. 34, T. 8, R. 22	22.00	18.69	5.61
Mean			2.77

The loss in other counties bordering the lake is less on the average.

A few measurements of the rate of erosion of the lake bluff near New Buffalo, Michigan, have been made by Mr. Glavin, formerly county surveyor. His measurements were made at dates ranging from 1870 to 1886. The land survey was made in 1829. The shortest period of erosion is therefore forty-one years, and the longest fifty-seven years. In one case (south line of sec. 8, T. 7 S., R. 20 W.) there has been a gain where a dune has encroached on the lake.

Erosion of the lake shore in Berrien County, Michigan.

Locality.	1829.	Years of erosion.	Annual loss.
	Chains.		*Feet.*
On range line between Rs. 20 and 21 W., from quarter post of sec. 30 north to lake	12.41	41	4.68
On line of secs. 25 and 36, T. 7 S., R. 21 W., from quarter post west to lake	34.00	46	8.68
On south line of sec. 35, T. 7 S., R. 21 W., from east end of line west to lake	76.90	41	2.25
From quarter post of sec. 17, T. 7 S., R. 20 W., north to lake	34.00	43	4.60
On south line of sec. 17, T. 7 S., R. 20 W., from quarter post west to lake	34.50	57	3.20
East line of sec. 8, T. 7 S., R. 20 W	34.73	56	5.24
South line of sec. 8, T. 7 S., R. 20 W	42.34	57	—3.30
North line of sec. 9, T. 7 S., R. 20 W., from quarter post west to lake	34.00	45	1.11
Mean			3.30

The measurements by Mr. Glavin show but little more erosion than those reported by the Wisconsin survey. In view of these measurements the rate for the entire shore is probably scarcely more than half that of Dr. Andrews's estimates.

Dr. Andrews calls attention to the existence of a submerged terrace, which, he thinks, furnishes a ready means for determining approximately the original position of the shore, and consequently the distance which the bluffs have receded since the water occupied its present level. Where the shores are of drift clay the terrace generally has a breadth of from 2 to 6 miles, but at the south end of Lake Michigan it is nearly 10 miles. The west shore of Lake Michigan was examined in some detail between Chicago and Manitowoc and the terrace was found to have an average width of 3.98 miles. This terrace slopes gently outward to the depth of about 60 feet, when the bottom dips more rapidly to the deep water of the basin. It is thought by Dr. Andrews to be the product of wave action and is denominated by him the terrace of erosion. The time required for the formation of this terrace was computed by using the average width of the terrace as a dividend and the annual rate of erosion as a divisor. As the outer edge of the terrace is at the depth of 60 feet, the position of the old shore was assumed to be at a point where a line drawn from the top of the present bluff of the lake to the outer edge of the terrace would meet the surface of the lake. These estimates give the average position of the old shore, a distance of 2.72 miles from the present shore. Dividing this distance by the annual rate makes the total age of the terrace 2,720 years, or a duration nearly the same as that computed by the drifting of the sand. If the rate of erosion determined by the Wisconsin survey be substituted, the age would be 4,708 years.

The estimate based upon the rate of erosion of the shore of the lake is probably much more reliable than that based upon the drifting of the sand past the piers, but the great variability in the height of the shore (from 10 feet up to 100 feet or more) and the variability in the rate of recession (from 0 to 16.95 feet per year) makes it evident that the above computation is at best only a rude approximation. These estimates serve, however, as a provisional measurement of the duration of this stage of the lake and have much value in its bearing upon the length of postglacial time. Dr. Andrews remarks that they are useful in showing that it is impossible to allow, even on the most liberal estimates, any such postglacial antiquity as 100,000 years, which has often been claimed.

CHAPTER XII.

INFLUENCE OF THE DRIFT UPON DRAINAGE SYSTEMS AND DRAINAGE CONDITIONS.

Throughout almost the whole extent of the Wisconsin drift in Illinois and Indiana the preglacial valleys are filled so effectually that the present drainage is independent of them. The only notable exceptions are found in the lower part of the Illinois and Wabash valleys. Within the Wisconsin drift the morainic ridges often constitute water partings, while the plains between them carry drainage lines having courses nearly parallel with the ridges. In the Iowan drift area and in the portion of the Illinoian drift in western Illinois and southeastern Iowa, it is frequently possible to determine the courses of preglacial drainage lines and of the divides between them, though the streams conform to preglacial features only in a rude way. In southern Illinois and southwestern Indiana, for about 75 miles north from the extreme limits of glaciation, or to about the latitude of St. Louis, Missouri, and Terre Haute, Indiana, the drift is so thin that it has not greatly changed the main arteries of drainage from the lines followed by preglacial streams. The smaller streams, however, are often found to follow courses independent of preglacial lines, and the great majority are only partly coincident with them. The influence of glaciation, as already noted, has also extended into outlying districts and caused the deflections of streams whose lower courses or outlets were so situated as to be obstructed by the ice sheet or by its deposits. The influence of the drift is, therefore, very marked in all parts of the region under discussion and becomes a question of importance in the interpretation of the drainage development.

Inasmuch as the influence of the drift varies greatly, the following designations are made, to indicate, in their order of importance, the relative amounts of change produced by it:

(*a*) New drainage systems.
(*b*) Major stream deflections.
(*c*) Minor stream deflections.
(*d*) Reestablished or nondeflected drainage.

With the exception of drainage systems which are new throughout, the drainage lines often embrace two or more of the phases just outlined. This can not, therefore, well be made a basis for classification. A grouping about the main drainage lines will perhaps best serve our purpose. The discussion begins at the northwest with the Mississippi Valley and proceeds south and east.

THE MISSISSIPPI VALLEY.

The present Mississippi River has evidently a system of drainage widely different from the system or systems which were operative in preglacial times within the region now drained by it. Besides opening a new channel at each of the rapids, the stream apparently is occupying sections of two or more independent preglacial valleys. It may not be possible at present to determine what relation the several sections sustained to one another in preglacial time, much less to show the relation to the great systems by which the interior of North America was drained.

ACCESSION FROM THE NORTH (?).

Hershey has recently written a paper in which he maintains that the present Mississippi at Dubuque is out of proportion to the valley that it occupies.[1] Upon comparing it with neighboring streams whose sources are within the Driftless Area, and whose valleys are cut in formations similar to those of the Mississippi at Dubuque, he concludes that the preglacial stream flowing past Dubuque could not have been larger than the present Rock River, and was possibly as small as the Pecatonica. The Mississippi presents bluffs which are somewhat steeper than those of tributary valleys. In many places they are perpendicular precipices, and they are rarely sufficiently sloping to support a growth of trees. The tributary valleys excavated in the same rock formations have wooded slopes, rather steep, but rarely bare precipices. Hershey remarks concerning this portion of the Mississippi: "I have never yet come upon its canyon valley without being impressed with its general appearance of greater youth than others of apparently the same system."

[1] The physiographic development of the Upper Mississippi Valley, by Oscar H. Hershey: Am. Geologist, Vol. XX, 1897, pp. 246-268.

The precise position of the supposed divide is not given, but is suggested by Hershey to be south of the mouth of the Wisconsin River, where the "Military Ridge" is crossed by the present river. Northward from this supposed divide the valley now occupied by the Mississippi is thought by him to have been occupied by a stream "flowing toward central Minnesota instead of away from it."

The geological date of the change is regarded as somewhat uncertain, though Hershey thinks it probable that it occurred during the advancing stage of the earliest glaciation in the region to the north. The advance of the ice sheet into the lower course of a northward-flowing stream would naturally cause the turning of the drainage southward over a low divide. This may have occurred long before the culmination of the Kewatin ice sheet. An alternative view, also suggested by Hershey, refers the reversal of drainage to an uplift of the northern portion of the Mississippi Basin. By either view the date of reversal is placed by him near the close of the Ozarkian (or post-Lafayette) epoch of erosion, rather than at an earlier time.

MINOR DEFLECTION AT FULTON, ILLINOIS.

The preglacial valley, thus enlarged by accession of waters from the north, has been but partially filled with drift as far south as Clinton, and is occupied by the present stream except for a space of about a mile, just above Clinton, where a rocky point on which the village of Fulton, Illinois, stands, has been cut off from the Iowa side. The old valley still furnishes escape for flood waters around the eastern end of this rocky point. These features are well displayed on the Clinton topographic sheet of this Survey, which is here reproduced (Pl. XVIII).[1] The cause for this course across a projecting point of the west bluff is not easy to determine, and seems especially remarkable because of the unobstructed condition of the old valley. Before speaking further concerning the cause, a similar feature in a neighboring township is considered.

An equally singular deflection of a stream, shown also on Pl. XVIII, is found in the lower course of Elk River, which enters the Mississippi from the Iowa side about 7 miles above Fulton. The stream leaves a

[1] In the inspection of this sheet it is necessary to allow for 20 to 30 feet of loess on the higher part of the rocky point, thus reducing the rock to about 70 feet above river.

broad valley which opens southward into the Mississippi, and passes eastward across a narrow point of uplands separating this valley from the Mississippi. The old valley, though covered heavily with loess, stands only 40 to 50 feet above the present stream bed, while the rock ridge rises promptly on either side of the deflected stream to a height of about 100 feet above the abandoned valley.

The deflections, it will be observed, are each situated near the margin of the Kansan and also of the Iowan drift of the western ice field, as well as the margin of the Illinoian drift of the eastern ice field. It becomes, in consequence, no easy matter to decide upon the influence which each ice field may have exerted in causing these peculiar features. In the Mississippi deflection at Fulton the stream has been shifted to the west, as if due to obstructions on the east, while in the Elk River deflection the stream has been shifted to the east, as if the obstruction were on the west. However, it is not certain that the deflections are directly due to ice advances. Upon examining the ground with a view to interpreting the features, it appears probable that encroachment by the Mississippi through a widening of the valley may in each case have so broken down a portion of the crest of the narrow dividing ridge that displacement could have been brought about by only a slight filling of the valleys, such a filling perhaps as the loess produced. It will be observed that the present course of each stream is more direct than the old course. This may aid in accounting for their persistence in the new lines. This interpretation, however, is not wholly satisfactory.

DEFLECTION PAST THE LECLAIRE OR UPPER RAPIDS.

Immediately below Clinton the glacial deposits attain sufficient thickness to completely disarrange the old drainage and to render it very difficult to determine the course of the preglacial stream. A special study of the preglacial course was made for this Survey by Prof. J. A. Udden, the main results of which he has kindly furnished for publication in this report.

The present course across the rapids has apparently been selected by the Mississippi in preference to several lines which had been opened, and is the most direct of these lines. The rapids proper extend from Leclaire, Iowa, down to Rock Island, Illinois, a distance of nearly 15 miles. There is a fall at low water of 20.4 feet, or an average slope of about 16½ inches to the mile. The rapids, however, do not present a uniform slope, but

consist of a series of rock barriers, called "chains," separated by pools or stretches of slack water. The slope also is greatest in the lower portion, about half the fall occurring in the last 5 miles. The narrowness of the valley in this new course is well shown in Pl. XVIII. It averages scarcely 1 mile.

The uplands immediately bordering the narrow portion of the Mississippi Valley stand 100 to 120 feet above the stream. They carry a capping of loess 30 or 40 feet in average depth, beneath which there is a sheet of drift ranging in depth from a mere trace to 75 feet or more. In the portion below the bend, just south of Leclaire, the drift extends down about to the level of the present river bed, but from Leclaire northward the rock rises 50 to 75 feet above the river. The rock cutting accomplished by the river is even less than these figures would indicate, for there appears to have been a small preglacial stream leading northward from the vicinity of Leclaire, whose valley may have been widened but little by the river, and whose rock floor extends below the level of the present stream. The rock excavation is, therefore, confined mainly to a short section 2 or 3 miles in length, in the vicinity of Leclaire, and even here the cutting has reached a depth of scarcely 75 feet.

One of the abandoned drainage lines above referred to, known as "Cattail Slough," leads southeastward from a point in the Mississippi Valley opposite Clinton, as shown in Pl. XVIII, to join Rock River Valley at Erie, Illinois. Another, Meredosia Slough, leaves the Mississippi opposite the mouth of the Wapsipinicon River, a few miles below Clinton, and leads southeastward to Rock River Valley below Erie. Each of these channels is so low that it may be utilized either by Rock River or by the Mississippi at flood stages of those rivers. From Erie (see Pl. XVIII) two channels lead westward to the Mississippi, one along the present course of Rock River, the other along Pleasant Valley, which is nearly parallel with it on the north.

The distance along the present course of the Mississippi from the northwest end of Meredosia Slough to the point where Pleasant Valley connects with the river is only 12 miles, while the course by way of the slough and valley is fully twice that distance. The course by way of Cattail Slough and Rock River is also fully double that by the present Mississippi. The narrowness of the valley of the present stream from Cordova to Hampton,

Illinois, is in striking contrast even with Pleasant Valley and the portion of the Mississippi immediately below, though these valleys are much narrower than the valley above the point where this deflection occurs.[1]

Pleasant Valley, as interpreted by Udden, appears to mark the line of a preglacial stream which discharged eastward, carrying probably the drainage of the district now tributary to Duck Creek, which enters the Mississippi opposite the western end of this valley. Possibly it carried the drainage of a valley heading near Fairport, Iowa, a few miles above Muscatine, or the course of that drainage line may have been eastward along the present lower course of Rock River, reversed. Udden locates the divide near Fairport because of the height of the rock bluffs at that point, their elevation above the river being about 175 feet, and because of the eastward slope of the valley floors of the small tributaries of the Mississippi in the section immediately east of Fairport. It appears from the study of these tributary valleys that the preglacial rock cutting had extended nearly to the level of the present stream before entering Pleasant Valley or the lower course of Rock River Valley. The principal part of the rock cutting along the Mississippi below Rock Island has been in the immediate vicinity of Fairport, where for a space of perhaps a mile it may have reached a depth of 150 feet. The amount of rock excavation appears to be greater in the divide near Fairport than in the one crossed near Leclaire, yet the rock barrier has been more effectually removed at the Fairport than at the Leclaire divide. This may be due in part to the more yielding nature of the rock near Fairport, where it consists in the main of soft Coal Measures, and in part to longer cutting at Fairport.

The question of the date of the deflection of the Mississippi across the Leclaire Rapids is of much interest, though as yet a fully satisfactory solution has not been reached. Were the course of the present stream past Leclaire the only one to be considered, a study of the work accomplished by it might afford a means for estimating the time required in the excavation compared with that of the excavation of channels whose date has already been established. But the fact that the energies of the Mississippi

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[1] Attention has already been called to a temporary course of the Mississippi across eastern Iowa, but this course seems to have been abandoned during if not prior to the Iowan ice invasion and did not persist so long as these courses through the abandoned channels connecting the Mississippi and Rock River valleys.

have been divided among the several lines referred to above renders it difficult to estimate the work accomplished. It, however, helps us to appreciate the cause for the exceedingly small amount of excavation accomplished by the stream in its present course. It also suggests an explanation for the greater amount of excavation accomplished in the removal of the Fairport divide, since the entire energies of the Mississippi appear to have been expended on that divide throughout the time since the course across the Leclaire Rapids came into operation.

In the discussion of the temporary displacement of the Mississippi into a course outside the limits of the Illinoian drift (which seems to have occurred during the culmination of the Illinoian invasion), it was suggested that the Mississippi may have maintained its flow through the lower courses of the Cedar and Iowa rivers, until the invasion of the ice from the west at the Iowan stage of glaciation forced it into a course farther east. If this suggestion proves true, the establishment of the present course of the Mississippi across the Leclaire Rapids, and also the occupancy of the abandoned channels, Cattail Slough and Meredosia Slough, may be referred with some confidence to the Iowan stage of glaciation. Possibly the Rock River drainage had been opened westward past Fairport at an earlier date, though it seems quite as probable that Rock River would have connected either to the west, through the Meredosia Slough, with the Mississippi, or passed southward into the Illinois, as it appears to have done in preglacial time. The complexity of the channeling is such as to demand further field examination or further deliberation before a satisfactory interpretation can be set forth.

The question of the preglacial course of the Mississippi below Clinton remains to be considered. Udden's special investigation has led him to the conclusion that the preglacial line must have been along one of two courses, either southeastward through the Meredosia Slough and Green River Basin to the Illinois at the bend near Hennepin, or directly westward through the Wapsipinnicon Basin to the mouth of Mud Creek, and thence southwestward along the Mud Creek sag to the Cedar; thence the course may have been by way of the present Cedar and lower Iowa, or more directly southward to the Mississippi just west of the meridian of Muscatine. Udden has collected well data along the Mud Creek sag showing that a buried channel occurs there whose rock floor is more than 100 feet below the level of the

Mississippi River at Clinton, and perhaps sufficiently low to have carried the drainage of the preglacial stream whose valley has been traced southward to Clinton. The data are scarcely sufficient to fully establish the connection of this channel across the Wapsipinnicon Basin, for there are very few deep wells in the basin. Another feature which throws some doubt upon this connection is the narrowness of the deep portion of the channel along the Mud Creek sag. The well data indicate that its width can not exceed 2 or 3 miles, and this seems rather narrow for the continuation of so broad a valley as that above Clinton, a valley 4 or 5 miles in width.

Turning to the southeastward course, one finds a broad depression or lowland tract leading from Clinton through to the Illinois River. This lowland, except at the outer moraine of the Wisconsin drift in Bureau County, stands only a few feet above the level of the Mississippi, and yet apparently carries a heavy accumulation of drift. The drift is largely sand, and there has been no necessity for sinking wells entirely through it. They have, however, penetrated 40 to 50 feet without striking rock. The bed rock gradually descends from each side toward the middle of the lowland, and some of the creeks coming into the lowland occupy large and deep channels which have been only partially filled with drift. This rather throws the balance of evidence in favor of the view that the preglacial stream flowed southeastward into the Illinois.

It should be observed that in case the southwestward route proves to have been the course of the Mississippi, the present line of the stream departs from it only a few miles and enters the same old valley below Muscatine, which it occupies above Clinton. But in case the southeastward route proves to have been the preglacial course from Clinton, the preglacial valley above Clinton finds its continuation down the Illinois instead of down the Mississippi, and the present Mississippi passes from one drainage system to another in its course between Clinton and Muscatine.

REESTABLISHED STREAM BETWEEN THE UPPER AND LOWER RAPIDS.

From the city of Muscatine southward to the head of the lower rapids, 12 miles above Keokuk, Iowa, the Mississippi River is flowing through a broad preglacial valley. It has removed the drift throughout only a portion of the width of the old valley in the district between Muscatine and

the mouth of the Iowa River. But in the section below the mouth of the Iowa, as far as the mouth of Skunk River, it coincides in width with the old valley. For a few miles in Lee County, Iowa, in the vicinity of the city of Fort Madison, only a part of the width of the preglacial valley has been opened (see fig. 4), but just before entering the rapids the present valley expands to about the full width of the old valley.

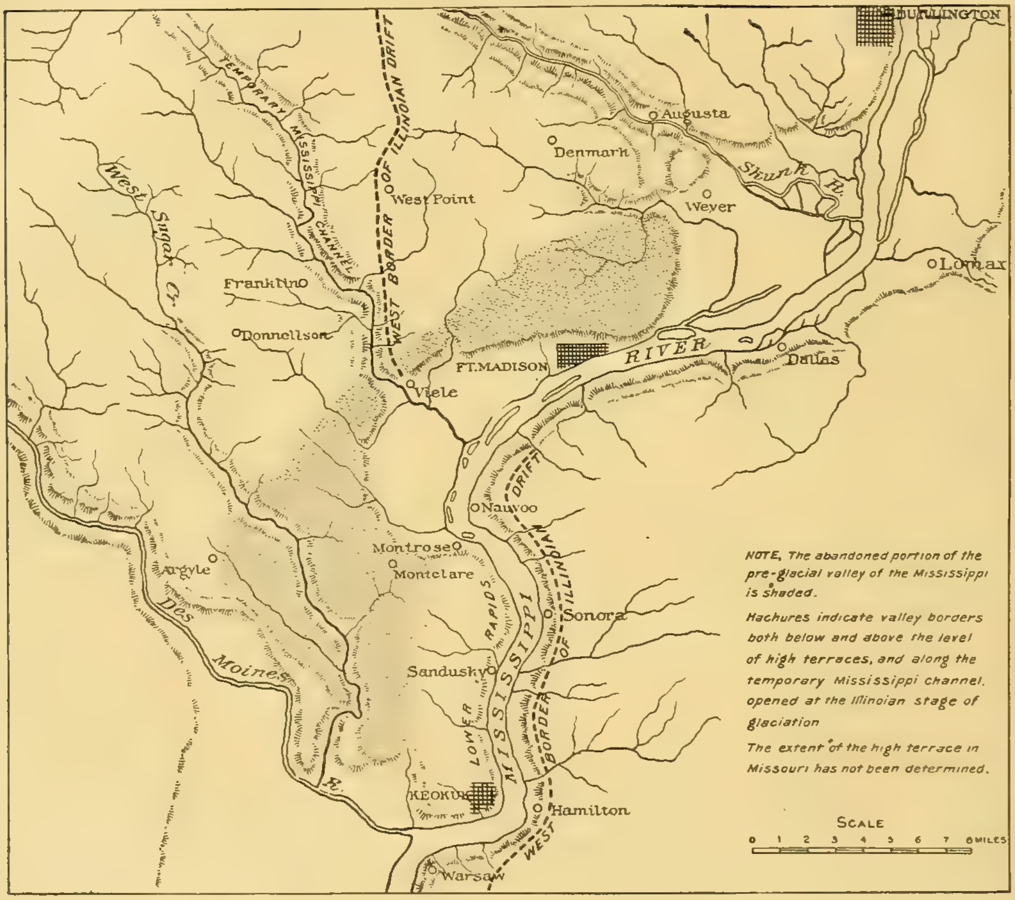

FIG. 4.—Sketch map of the region bordering the lower rapids of the Mississippi River.

The present bed of the Mississippi is 100 feet or more above the rock floor of the preglacial valley throughout the entire distance between Muscatine and the lower rapids. A rough estimate of the relative sizes of the present valley and the preglacial valley in this section shows the preglacial valley to be fully twice as large as the present valley. The present valley has an average depth of about 150 feet and an average breadth of about 6

miles, while the preglacial valley has a breadth ranging from 6 to 15 miles and a depth of about 250 feet below the level of the bordering rock bluffs.

DEFLECTION AT THE LOWER RAPIDS.

The preglacial channel, as long since pointed out by Gen. G. K. Warren,[1] and subsequently elaborated by Prof. C. H. Gordon,[2] passed southwestward across southern Lee County, Iowa, entering the broad valley of the Mississippi just above the mouth of the Des Moines River. (See sketch map, fig. 4.) Its east bluff, as determined by Gordon, is only 3 or 4 miles west of the present stream. The deflection, therefore, is much smaller than in the case of the upper rapids. In its new course across the rapids and thence west into the old valley the channel has a length of about 15 miles. The filled portion of the preglacial channel west of it has a length of only 8 miles, being more direct than that of the new course.

The preglacial channel has, in its abandoned portion, about the same width as in the reestablished portions above and below, and is shown by an artesian well at Montclare to reach a level about 125 feet below that of the present river bed at the head of the rapids. The accompanying diagrammatic section (fig. 5), prepared by Gordon, sets forth the relative size of the preglacial and present valleys and the position of this boring. The depth of rock excavation in the old channel is estimated by Gordon to be 245 feet, and the width 6 miles,

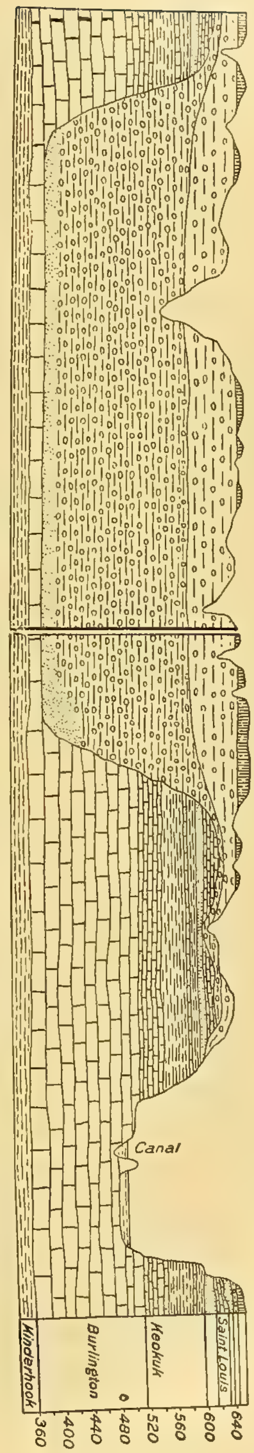

Fig. 5.—Section from Sonora, Illinois, to Argyle, Iowa, showing the present and the preglacial valleys of the Mississippi River. It crosses the Mississippi near the head of the "Lower Rapids." The boring in the preglacial valley is at Montclare, Iowa. [Modified from fig. 2, Pl. XXVIII, Iowa Geological Survey, Vol. III.]

[1] Bridging of the Mississippi: Ann. Rept. Chief of Engineers, U. S. Army, 1878, Appendix X, pp. 916–917, Diagram E; also Diagram 1, sheet 4.

[2] Buried river channels in southeastern Iowa: Iowa Geol. Survey, Vol. III, for 1893, pp. 239–255, figs. 5 and 6, Pl. XXVI. Published in 1895.

while the new channel has an estimated rock excavation ranging from 60 to 135 feet in depth and scarcely 1¼ miles in width. Probably the average depth of rock excavation in the new channel is less than 100 feet.

The lower rapids have a length of 11.1 miles, the head being at Montrose Island and the foot a short distance above the river bridge at Keokuk. From the foot of the rapids there is a narrow valley leading westward about 4 miles to the broad preglacial valley. The total descent in the rapids is 22.17 feet, or very nearly 2 feet to the mile. The rate of descent, as in the upper rapids, is greatest in the lower part, there being a fall of about 4¼ feet in the lower mile and nearly 8 feet in the lower 2 miles.[1] Above this part the fall, though not uniform, is less definitely broken into rapids and pools than at the upper rapids. Indeed, there appears to be a rock floor forming the river bed throughout the entire length of the lower rapids.

A question of much importance is found in the determination of the date at which the Mississippi entered upon the work of excavating its new channel past the lower rapids. The difficulties attending the solution of this question are great, and have been discussed in a special paper by the writer.[2] The main points set forth in that paper are outlined below. The deflection being toward the east, the drift filling which caused the displacement in all probability took place as a result of the invasion of the Kewatin ice field at the Kansan stage of glaciation. But it is not definitely settled that the present course across the rapids was adopted upon the retirement of the Kewatin ice, since there is a possibility that the displacement was farther to the east. The coincidence of the present course with the western border of the Illinoian drift suggests the question whether the river may not have adopted this course as late as the time of the Illinoian invasion.

Attention has already been called to the great erosion of Kansan drift along the Mississippi below the lower rapids which occurred prior to the valley filling that seems to have accompanied the Illinoian stage of glaciation. The pre-Illinoian excavation appears to have been nearly as great as

[1] The following data are obtained from Greenleaf's report on Water Power of the Mississippi and Tributaries: Tenth Census of United States, 1880, Vol. XVII, p. 60. "In the first 4,800 feet from the lower lock there is a rise of 4.21 feet, then 2.22 feet in the next 3,600 feet, and 1.67 feet in the succeeding 3,600 feet to the middle lock, making the fall in ordinary low water from a point opposite the middle lock to the foot of the rapids 8.1 feet."

[2] The lower rapids of the Mississippi River, by Frank Leverett: Jour. Geol., Vol. VII, 1899, pp. 1-22.

the post-Illinoian, and therefore much too great to refer to the work of the Des Moines River. But while there seems clear evidence that the channel across the rapids was begun by the Mississippi before the culmination of the Illinoian invasion, it may not follow that it was occupied by that drainage from the close of the Kansan invasion. The probable effect of the Kansan invasion would be to throw the stream to the east of the preglacial course. Furthermore, since the ice sheet at that stage extended beyond the line of the Mississippi at the lower rapids, the displaced river would naturally take a course through the lowest available district east of that ice margin. This being done, it may have persisted in that course for some time after the culmination of the Kansan stage of glaciation, and possibly until the Illinoian invasion crowded it westward to the present line. The amount of excavation preceding the culmination of the Illinoian glaciation, however, favors the view that its selection of the course across the lower rapids was made soon after the retreat of the Kansan ice sheet.

The value of the lower rapids as a chronometer for determining the time since the Kansan invasion, as well as the relative dates of the Kansan, Illinoian, Iowan, and Wisconsin stages of glaciation were considered in the paper just referred to, and the main difficulties were discussed. One great difficulty lies in the fact that there was not a continuous rock excavation. At both the Iowan and the Wisconsin stage some filling occurred, and at the Illinoian stage also it is probable that the filling predominated over the cutting. A further difficulty is found in the fact that the drainage basin of the Mississippi above these rapids has suffered great changes in area since the Kansan stage of glaciation, thus greatly affecting the volume of the stream. The work done at the rapids may be roughly stated as follows:

(1) The excavation (independent of filling at the Illinoian, Iowan, and Wisconsin stages of glaciation, which was subsequently largely removed) comprises (*a*) the removal of a drift deposit capping the limestone which had an average depth of perhaps 25 feet, a length of 15 miles, and a width of $1\frac{1}{2}$ miles; (*b*) the removal of limestone to an average depth of nearly 100 feet for a length of at least 12 miles and a width of about $1\frac{1}{4}$ miles. The excavation of limestone is estimated to be nearly one-third of a cubic mile.

(2) A filling of undetermined amount, but apparently not less than 30 feet, correlated with the Illinoian stage of glaciation, which is well shown by the sections at Warsaw and at Yellow Banks below the lower end of the

rapids (discussed on a preceding page), and following this filling a nearly complete removal of it along the rapids.

(3) The Iowan loess filling, also of undetermined amount, but probably 15 feet or more, and following this a nearly complete removal along the rapids.

(4) The Wisconsin sand filling, which seems to have raised the river bed about 50 feet, followed by a nearly complete removal along the rapids.

It would be very difficult to estimate the work involved in filling, even though the depth of filling in the vicinity of the rapids were known. The filling is simply an index of the excess of the material brought in over the transporting power of the stream. To properly estimate the work done in a stage of filling, it would be necessary to compute the amount of material carried through the channel as well as that deposited in it. In the case of the lower rapids, it seems doubtful if such computations can be made.

The uncertainties involved in changes of drainage area are fully as great as in the work of filling. Some data showing the effect of a change of volume upon the gradient of the river are cited by General Warren. At the time when Lake Agassiz discharged through the Mississippi the stream appears to have opened its channel in the Upper Mississippi to a depth in harmony with the bed of Lake Pepin, which is about 60 feet below present low water. The lesser volume of water now passing down the Mississippi has proved inadequate to remove the detrital dam built at the mouth of the Chippewa River (which is at the lower end of Lake Pepin), and thus the bed has been raised in that vicinity about 50 feet. It is thought by General Warren that a filling is now in progress along the greater part of the Mississippi above Cairo as well as below, and that the rapids are the chief places where a marked cutting is now in progress.[1]

In view of all these qualifying conditions, it seems hazardous to venture a comparison of the work of the Mississippi at the lower rapids with that of the streams on which estimates have been made, or at least to base definite conclusions upon such a comparison.

In closing this discussion attention is called to the contours of the bluffs of the channel along the rapids and to the rate of fall in the rapids. The contours of the bluffs favor the view that excavation began soon after the

[1] Bridging of the Mississippi: Ann. Rept. Chief of Engineers, U. S. Army, 1878–79, pp. 912–917.

Kansan stage of glaciation, and has proceeded very slowly down to the present stream level. Except at a few points where the river in rounding a curve is encroaching on its bluff, the rise is gradual from each bank to the brow of the bluff, so that a large part of the slopes may easily be cultivated. Although the bluffs are largely a firm limestone, they recede about as much as the bluffs formed in glacial deposits at the upper rapids. Their age, therefore, appears to be several times as great as that of the upper rapids.

The work performed in cutting away the rock barrier is many times greater than at the upper rapids. No "chains" rise above the general level, as at those rapids, and the fall has been reduced to a very moderate rate.[1] Cutting now proceeds very slowly at these rapids, for the river carries but little sediment except at flood stages, and these extend over but a few weeks of the year. If all the features of the new channel be considered, together with the fact of the occurrence of long stages of interruption from cutting, there seems little to oppose the view that the opening or selection of this course may have been at so remote a date as the Kansan stage of glaciation.

REESTABLISHED STREAM BELOW THE LOWER RAPIDS.

The disturbance of the Mississippi Valley drainage below the lower rapids is mainly restricted to the first 50 miles, between Keokuk, Iowa, and Hannibal, Missouri, where the western or Kewatin ice field at the Kansan stage of glaciation seems to have covered the valley and extended a few miles beyond it. This portion of the valley was left open at the Illinoian stage of glaciation. There is, however, a bare possibility, as noted above, that the Illinois lobe encroached slightly upon the Mississippi Valley just above St. Louis. The disturbance of drainage was but temporary at either place, and the present river is fully reestablished in the preglacial course. Its valley bottoms are as wide as those of the preglacial river and range from 5 to nearly 10 miles in width. The rock bottom of the preglacial valley, like that of the section above the rapids, is considerably below the level of the present stream, as shown by the table presented below.

[1] It is probable that in the early part of the opening of this new channel the gradient was much steeper than now, and possibly falls of some height existed. But as yet few definite criteria bearing upon this early condition of the valley have been recognized.

DEFLECTIONS SOUTH OF GLACIAL BOUNDARY.

It seems necessary to refer briefly to two slight deflections of the Mississippi, one of which is below the limits of glaciation and the other near the point where the glacial boundary bears eastward away from the Mississippi Valley. The former is certainly independent of obstruction by the ice, and the latter may be also. The deflection near the glacial boundary is at Fountain Bluff, Jackson County, Illinois, where a rocky point similar to that at Fulton has been cut off from the west bluff. The broad preglacial valley, as at Fulton, is still occupied by the stream at flood stages, but is much less direct than the course across the rocky point. In explanation of this peculiar feature it is suggested that the encroachments of the Mississippi upon the rocky point had so broken down the crest that a moderate silting up of the valley, which probably occurred during the loess deposition, enabled the stream to cross it. The persistence of the stream in this course is probably attributable to the more direct line of discharge. Possibly the presence of the ice in the valley immediately north and east of this rocky point was influential in diverting the stream across it. The deflection farther down the river is at Thebes, Illinois, where for a distance of about 6 miles the river is excavating a new course across a rock point which projects westward into Missouri. An inspection of this district shows that the altitude of the rock in the rocky point crossed by the stream is so low that it is necessary to assume but little silting up of the preglacial channel to have made it possible for the stream to take the present direct course, probably not more than 50 feet above the present level of the river. A silting of this amount may be supposed to have occurred during the loess deposition.

ROCK FLOOR AND PRESENT STREAM COMPARED.

In this discussion each of the preglacial valleys utilized by the present Mississippi are included. The data concerning the rock floor are obtained from well borings or from tests for bridges, but are not sufficiently full to show whether the lowest part of the valley floor has at any point been reached, much less do they indicate the lowest part at all points. It seems probable, however, that the majority are in the deep part, since they are located near the middle of the preglacial channel. They at least indicate approximately the depth of preglacial excavation, and it is thought that they throw some light upon the slope of the rock bottom.

In the table which follows it will be observed that the rock bottom has a lower altitude at St. Paul, Minnesota, than at several points farther down the present stream, a feature which is thought to sustain the interpretation made by Hershey, that a divide has been crossed between St. Paul and Dubuque. In a paper prepared by the writer a few years ago[1] this low altitude at St. Paul and vicinity was suggested to be due either to northward differential depression or to a local deepening, such as might have resulted from a waterfall or from subglacial erosion by water or ice. However, no evidence of the operation of these agencies has been discovered, and they could not have been operative within the Driftless Area. These suggestions do not, therefore, seem so pertinent as the interpretation made by Hershey.

Altitudes of rock bottom and present Mississippi.

Location.	Distance.	Low water, above tide.	High water, above tide.	Rock floor, above tide.
	Miles.	*Feet.*	*Feet.*	*Feet.*
St. Paul, Minn	0	683	702	*a* 483
Lake City, Minn	55	658	(?)	*b* 495
Winona, Minn	40	639	656	*c* 503
Lacrosse, Wis	20	628	643	*d* 504
Prairie du Chien, Wis	60	604	623	*d* 492
Dubuque, Iowa	55	585	607	*d* 453
Sabula, Iowa	36	572	592	*e* 429
Fulton, Ill	16	566	587	400±
Leclaire, Iowa (new channel)	20	562	576	550
Rock Island, Ill. (new channel)	16	542	560	530
Muscatine, Iowa (new channel)	24	531	547	506
Near Wilton, Iowa (old channel)				*f* 400—
Near Muscatine, Iowa (old channel)	2	530	547	*g* 388
Mouth of Iowa River	18	523	539	445—
Burlington, Iowa	24	511	527	430—
Fort Madison, Iowa	18	502	518	*h* 365

a N. H. Winchell, Am. Geologist, Aug., 1892.
b Geol. of Minnesota, Vol. II, p. 17.
c Data furnished by Dr. U. S. Grant in letter.
d Chamberlin and Salisbury, Sixth Ann. Rept. U. S. Geol. Survey, p. 223
e Data given by W. R. Oake, ex-mayor of Sabula.
f A well at this point, reported by Udden, failed to reach rock at elevation 400 feet above tide.
g Two wells in the valley below Muscatine, reported by Udden, reached rock at a level about 142 feet below the low water level of the Mississippi.
h C. H. Gordon: Geol. of Iowa, Vol. III, 1893, p. 246. A well one-half mile north of Fort Madison reached a level about 365 feet above tide without entering rock. The channel may, therefore, be deeper than that shown by the Fort Madison wells.

[1] Jour. Geol., Vol. III, 1895, pp. 740-763.

Altitudes of rock bottom and present Mississippi—Continued.

Location.	Distance.	Low water, above tide.	High water, above tide.	Rock floor, above tide.
	Miles.	*Feet.*	*Feet.*	*Feet.*
Montclare, Iowa (old channel)				*a* 374
Montrose, Iowa (new channel)	9	500	514	490
Keokuk, Iowa (new channel)	12	477	494	475
Quincy, Ill. (rock shelf)	38	458	476	*b* 413
Hannibal, Mo	17	450	467	*c* 362
Louisiana, Mo	25	437	453	*d* 380—
Mouth of Illinois River	68	403	422	(?)
Bellefontaine, Mo. (on Missouri River)	17	402	420±	*e* 295
East St. Louis, Ill	24	380	414	*f* 284
East Carondelet, Ill. (on rock shelf?)	6	377	412	330
Fountain Bluff, Ill. (new channel)	100	313	357	300
Near Wolf Lake, Ill	15	305	350	*g* 255—
Thebes, Ill. (new channel)	25	291	339	280
Cairo, Ill	35	270	321	(?)

a Beck's artesian well, at Montclare; see Geol. of Iowa, Vol. III, p. 247; also this report, fig. 5.
b Bridge piers rest on a rock shelf 35 to 40 feet below low water: Rept. U. S. Army Engineers, 1878.
c Data concerning channel piers furnished by W. S. Lincoln, chief engineer of Wabash Railroad, St. Louis, Missouri.
d Bed of present stream is 380 feet above tide: Rept. U. S. Army Engineers, 1878.
e Missouri River Commission, Rept. for 1890. The low-water altitude here given is on the Missouri.
f Data concerning depth to rock at bridge piers furnished by Robert Moore, C. E., St. Louis, Missouri.
g A well made by Bolin Sublette failed to reach rock at 50 feet below river level.

The fact that the rock bottom in this and other valleys of the Upper Mississippi region lies considerably below the present streams has often been cited in evidence of a great preglacial altitude of the region. This interpretation seems questionable, inasmuch as there appears to be an adequate fall to the seaboard from the rock floors of these valleys, even though the altitude were no greater than at present. In the valley under consideration the rock floor in the 210 miles between Fort Madison, Iowa, and St. Louis, Missouri, makes a descent of about 80 feet, or 4½ inches to the mile, and stands sufficiently high at St. Louis to maintain a similar fall to the Gulf were a direct channel to be opened. A somewhat similar gradient appears also to be maintained in the portion above Fort Madison. Although the gradient is somewhat lower along the rock floor than that of the present Mississippi, it is about as great as that of the present Ohio, which has a fall of but little more than 5 inches to the mile in the 967 miles from Pittsburg to Cairo.

The breadth of the valley excavation seems also to support the view that it was produced under a moderate or low rather than a high stream gradient. It seems improbable that a stream which was cutting down rapidly could have formed a valley several miles in width such as appears along the line of the Mississippi below Muscatine, or along the line of other preglacial valleys occupied by the Mississippi above Clinton. So far as known, the preglacial channels under consideration have furnished no positive evidence of the existence of narrow trenches cut below the general level of their rock bottoms. A few rock shelves have been found extending out a mile or more, as at Quincy and St. Louis, but these occur at points where the river has, in comparatively recent time, been encroaching upon the rock bluffs, and may, therefore, be a more recent product than the deeper part of the valley. In the present state of knowledge it certainly seems unsafe to cite them in evidence of a preglacial gradation plane standing above a lower part of the rock bottom.

MINOR TRIBUTARIES OF THE MISSISSIPPI.

Since the Illinoian invasion encroached only a few miles upon the district west of the Mississippi (in the southeastern part of Iowa), it has not greatly influened the course of the western tributaries. The larger western tributaries in southeastern Iowa, as above noted, were temporarily deflected southward along a course immediately outside the Illinoian ice border, but these have regained the courses opened prior to the Illinoian invasion. The tributaries here discussed are, therefore, mainly on the eastern side of the Mississippi. The discussion begins in northern Illinois and the streams are taken up in order southward.

APPLE RIVER.

A few streams lie wholly within the driftless portion of northwestern Illinois and adjacent parts of Wisconsin and may, therefore, be passed by, since they maintain their preglacial courses. It is, however, necessary to mention one stream, Apple River, which lies almost wholly within the limits of the Driftless Area, but which has received a marked accession of drainage because of the blocking of a preglacial tributary of the Pecatonica. This diversion occurs just below the village of Millville, as shown in Pl. XII. For about 3 miles below Millville the stream is in a gorge but little wider than its bed. The small preglacial Apple River is then entered.

PLUM RIVER.

Plum River lies partly within the Driftless Area, but its lower course and two important eastern tributaries traverse glaciated districts on the southeast border of the Driftless Area. By reference to the Savanna topographic sheet it will be seen that the stream passes through a gorge in southwestern Woodland Township, Carroll County, which apparently was formerly the site of a divide between the Plum River drainage and a much smaller stream entering the Mississippi at Savanna. The course of the preglacial Plum River was probably southward through the glaciated district, along a line a few miles to the east of its present lower course, but as yet the precise location of the valley has not been ascertained. Carroll Creek, one of the principal eastern tributaries of Plum River, apparently discharged southward through Johnson Creek Valley, from a point immediately east of Mount Carroll. It now passes westward through a series of gorges in the vicinity of Mount Carroll and enters a small preglacial valley about 2 miles west of that city. The interval between Carroll Creek and Johnson Creek is completely filled with drift for a distance of about 4 miles. The drift filling terminates abruptly near the point where the Chicago, Burlington and Northern Railway crosses Johnson Creek. From that point southward a preglacial valley fully a mile in width leads down to the Mississippi.

No stream of consequence enters the Mississippi on the east between Plum River and Rock River. As the latter stream constitutes one of the major tributaries, its discussion is taken up farther on. We pass, therefore, to the district south of the mouth of Rock River.

EDWARDS RIVER.

Edwards River, a stream which has a length of about 60 miles, leads westward from Henry County through Mercer County, Illinois, entering the Mississippi nearly opposite the mouth of the Iowa River. Its head-water portion consists of several streams which converge to form two forks that unite in south-central Henry County. From the junction of these two forks a remarkably direct westward course is taken, so that from points on its bluffs views may be had for several miles up or down the stream. This portion has only insignificant tributaries and drains a very narrow belt. The directness of its course and the narrowness of its drainage basin are

due to peculiarities of drift topography, there being in the district through which Edwards River flows a tendency to slight ridging in a general east-west direction, with broad, shallow depressions separating the ridges. Edwards River follows one of these depressions, while Pope Creek, which flows parallel with it on the south, follows a neighboring depression. A depression north of Edwards River differs from that of the two valleys just mentioned in separating its waters, a portion flowing directly west to the Mississippi through Copper Creek and a portion east and north into Rock River through Mill Creek. None of these streams, so far as the writer is aware, reach the bottom of the drift, yet it can not be assumed that they follow preglacial lines, for well sections indicate that the ridges and depressions are largely independent of the altitude of the underlying rock surface.

HENDERSON RIVER.

Henderson River, which drains much of northern Henderson, northern Warren, and part of Knox counties, Illinois, though having a length of scarcely 50 miles, furnishes a discharge through its numerous branches for an area of fully 500 square miles. The courses of the main branches seem to have no dependence either upon the underlying rock surface or upon drift topography. They traverse a very smooth district having gradual westward descent. The courses of the several streams are probably the result of slight advantages in the inclination of the slopes, at present difficult to discern. These streams have now in several instances cut down into the rock, and their courses seem to be independent of preglacial lines.

FLINT RIVER.

The first western tributary of the Mississippi to claim attention is Flint River, a small stream entering the Mississippi immediately north of Burlington, Iowa. Its source is in the marginal ridge of the Illinoian drift near New London, Iowa. The stream flows thence southeastward to the Mississippi across a gradually descending plain. It appears to disregard the courses of preglacial drainage lines, for in its upper course drift deposits extend in places to a depth of 250 feet, while in its lower course it has carved a channel through the rock ledges, whose cherty layers give to the stream its name.

LOST CREEK.

Lost Creek, a small western tributary of the Mississippi draining the eastern portion of Lee County, Iowa, occupies a valley markedly larger than other streams of its size which have cut channels in the Illinoian drift, a feature which appears to be due to an occupancy of the valley by a larger stream than the present one prior to the Illinoian ice invasion. The present head of the stream is in the marginal ridge of Illinoian drift near West Point. It seems not improbable that streams now draining southward through Sugar Creek found their outlet through Lost Creek Valley prior to the Illinoian invasion. The interpretation is rendered difficult because of the interruption made by the large stream channel of the temporary Mississippi, a channel which, as noted above, governs the present drainage of the streams outside the Illinoian drift from Skunk River southward.

BEAR CREEK.

Two small eastern tributaries of the Mississippi River remain to be considered—Bear Creek and Bay Creek. The former drains the southwestern part of Hancock and the northern part of Adams counties, Illinois. It has a widely branching drainage system, and the courses of the several tributaries were probably determined by the slope of the drift plain. One of the tributaries heading near Sutter leads northeastward for a few miles along "Big Meadow Channel," an abandoned valley of a larger stream, but turns away from that valley to form the north fork of Bear Creek. This north fork traverses a region of very thick drift, yet it may have no dependence on the course of preglacial drainage, but the lower course of Bear Creek evidently follows a preglacial line. The abandoned valley just mentioned is described below.

BAY CREEK.

This stream drains much of Pike County, Illinois. Its headwater portion leads from the north border of the county southeastward toward the Illinois, following a sag between two Illinoian drift ridges and nearly reaching the Illinois River, opposite the village of Bedford. It then curves around to the southwest, passes through a gap in the rocky ridge, which to the north and south constitutes the divide between the Mississippi and the

Illinois, and enters the Mississippi Valley opposite the town of Louisiana, Missouri. The deflection to the west is due to the ridge of Illinoian drift which follows the east border of the stream and prevents it from entering the Illinois Valley. The gap through the rock divide was apparently broken down below the level of the drift-filled districts to the east prior to the ice invasion, and thus offered no obstruction to the westward deflection of the drainage.

There are several small creeks entering the Mississippi between Bear Creek and Bay Creek, but which scarcely merit special mention, since they usually take a somewhat direct course to the river, following the slope of the drift surface. Those in Adams and northwestern Pike counties are in some cases deflected slightly by the drift ridges formed on the west border of the Illinoian drift, and find passage to the river through gaps in these ridges. In Pike and portions of Adams counties these creeks in part follow preglacial lines.

BIG MEADOW CHANNEL.

Under this name is discussed a channel which has been excavated in the Illinoian drift by a stream which long since ceased to flow. The channel is distinctly traceable in a course about S. 65° W. from near the town of Bushnell, Illinois, to the valley of the Mississippi in western Hancock County, a distance of 50 miles (see Pl. VI). Throughout its entire length the valley has bluff-like borders, which range in height from 20 feet to about 50 feet. In width it ranges from one-fourth to fully one-half mile. Its bottom is underlain by sandy and gravelly material, apparently alluvial, and there seems little question that it has been occupied and formed by a stream of considerable volume.

From near Bushnell the valley is now followed westward across McDonough County by East Crooked Creek. From the mouth of this stream the channel continues along Middle Creek (reversed) to the present divide between the Illinois and Mississippi drainage systems. In its passage across this divide it has cut a valley fully 40 feet in depth and more than half a mile in width. It is this portion which has long been known by the residents as the "Big Meadow." At the west it continues down Big Meadow Creek to another headwater tributary of Bear Creek, and thence follows the course of that creek (reversed) to the divide between Bear Creek

and the Mississippi near Sutter. The valley is here well defined and nearly as deep as at the "Big Meadow divide." From Sutter it leads down the valley of a small stream known as Rock Run, passing through a gap in the marginal ridge of Illinoian drift just before entering the Mississippi Valley. Throughout this entire distance of not less than 50 miles its course is remarkably direct.

The precise variations in the elevation of its bottom have not been determined. The eastern end near Bushnell, the "Big Meadow divide," and the divide at Sutter, all stand very nearly 650 feet above tide. With the exception of the descent into the Mississippi Valley west from Sutter, the slope of the valley bottom probably nowhere exceeds 5 feet to the mile, and is usually scarcely half that amount.

This singular valley appears to find its parallel in the valleys accompanying some of the eskers, an instance of which in Kane County has already been discussed (p. 284). No esker, however, lies in the "Big Meadow" Valley. It seems probable that the stream which excavated this channel was confined beneath the ice sheet, and thus held to a direct course across the low divides and shallow depressions covered by the ice. The hypothesis of a piracy of the stream which formed this channel by the two creeks which now drain it, Crooked Creek and Bear Creek, has been considered and seems untenable. The valley was evidently formed by a stream having much larger volume than either of these creeks possesses at the points where they depart from this old channel. Furthermore, the course of the channel is such as can scarcely be supposed to have been inaugurated without the confining influence of the ice sheet, for the present courses of drainage are determined by the general slopes of the region and are the natural lines of discharge. It seems, necessary, therefore, to refer this abnormal drainage to a subglacial stream.

In this connection it may be remarked that the system of parallel streams in McDonough County, all bearing west-southwest, may have been a result of slight channel development by subglacial streams along these lines. Similarly the depressions occupied by Edwards River, Pope Creek, and Copper Creek, in Mercer and Rock Island counties, may have been at first avenues of discharge for subglacial waters. There seems, however, in this latter district to have been a more decided development of ridges, parallel with the depressions, than is found in the vicinity of the "Big Meadow" channel.

ROCK RIVER DRAINAGE BASIN.

Rock River, which drains much of northwestern Illinois, has a length of nearly 300 miles and a drainage area of about 11,000 square miles. Nearly half its length and more than half its drainage area are in Wisconsin. Its general course is southwest from southern Wisconsin across northwestern Illinois. From its source to Janesville, Wisconsin, it traverses a region covered by drift of Wisconsin age, and its basin is characterized by extensive swamps and numerous small lakes. The drainage appears to be largely independent of preglacial lines. Just above Janesville the river crosses the outer or "Kettle" moraine of the Green Bay lobe, and soon enters a broad preglacial valley filled with a gravel deposit which heads in that moraine. The bordering uplands are covered by drift of Iowan age, as well as by earlier glacial deposits of Illinoian and possibly of still greater age. Below Janesville, with the exception of a few miles near its mouth in Rock Island County, Illinois, the present stream lies within the limits of the Iowan drift. The western border of that drift, however, extends but a few miles west of the stream at any point, and for a few miles below Rockford follows nearly the course of the river. The portion of this drainage basin lying outside the Wisconsin drift is generally undulating and well drained, but extensive swamps occur along Green River, an eastern tributary. The western tributaries lie mainly outside the limits of the Iowan, and the chief tributary, Pecatonica River, drains a small part of the Driftless Area.

The preglacial valley entered by Rock River near Janesville, Wisconsin, is followed southward a distance of 50 miles to the mouth of Kishwaukee River, a few miles below Rockford, Illinois. The river and valley there part company, the valley continuing southward and apparently connecting with the Illinois at Hennepin, the river turning southwestward to enter the Mississippi (see Pl. XII). In this southwestward course is found a series of small valleys separated by low divides which afforded the stream a means of escape without producing a great amount of rock excavation, as will appear from the detailed description given below.

THE PREGLACIAL DRAINAGE.

The preglacial valley entered by Rock River near Janesville may be traced without difficulty as far south as Rochelle, in southeastern Ogle

County, where a bulky moraine which forms the west border of the Wisconsin drift makes further tracing difficult. The valley has been so incompletely filled outside the limits of the Wisconsin drift that its rock bluffs rise perceptibly above the general level of the filling along the valley. But within the limits of the Wisconsin drift the valley has not only been completely filled but the general level of the drift surface rises 100 feet or more above its bluffs. Its course can be known, therefore, only through data obtained by deep borings. These indicate that it leads southwestward across eastern Lee and northeastern Bureau counties to Princeton, and thence southward to the bend of the Illinois River at Hennepin.

The breadth of the valley, in the portion exposed to view, averages about 3 miles, though it in places reaches nearly 5 miles. Its rock bottom appears to be somewhat lower than that of the preglacial valley occupied by the neighboring portion of the Mississippi. Chamberlin reports a boring at Lake Koshkonong, Wisconsin, which failed to reach rock at an elevation only 450 feet above tide. The rock was reached on the Mississippi in the same latitude at about 490 feet. Borings at Princeton, Peru, Bureau Junction, and Putnam, Illinois, enter rock at about 340 feet above tide, while borings on the Mississippi at Fort Madison, Iowa, which is somewhat farther south, reach rock at about 365 feet, though one boring failed to reach the rock at that elevation. No borings have been made between Lake Koshkonong and Princeton which are calculated to test the depth of the preglacial valley. Borings at Janesville, Wisconsin, and Rockford, Illinois, made at the foot of the west bluff, enter rock at about 530 feet above tide. They can scarcely be supposed to represent the depth along the middle of the valley opposite these cities. Several wells have been sunk in eastern and southern Lee County and in northeastern Bureau County, Illinois, which fail to enter rock, though they terminate at an elevation less than 500 feet above tide. From the data at hand it appears that the rock bottom descends from 450 feet or less above tide in southern Wisconsin to 340 feet above tide at the bend of the Illinois, 90 to 100 miles farther south.

Several of the large preglacial tributaries of the old valley may be traced readily in the district lying outside the limits of the Wisconsin drift. The Pecatonica River, which is the largest of the present tributaries, is

reestablished along the preglacial line, though the lower half of its course lies within the limits of the glacial district. The headwater portion of one of the western tributaries of the Pecatonica—Yellow Creek—has been diverted into Apple River, a tributary of the Mississippi. This stream also makes slight deflections into the bordering bluffs in its lower course. Sugar River, the principal northern tributary of the Pecatonica, occupies its preglacial line, except, perhaps, at the headwaters. Many of the smaller tributaries are also largely in preglacial lines.

Leaf River, which now drains a portion of northern Ogle County eastward into Rock River, is following a preglacial line which continued eastward across the present course of Rock River, through an abandoned channel known as "Stillman Valley," to the village of Stillman Valley, and thence northeastward to the old Rock River Valley in southern Winnebago County. Rock River follows the line of this preglacial valley for a few miles in the vicinity of Byron, but in the reverse direction from the stream which excavated the valley. Rock River also makes use of small tributaries of the preglacial Leaf River. From the mouth of the present Leaf River it passes up the valley of a small southern tributary for a few miles. Before entering the old Leaf River Valley east of Byron it has utilized a small northern tributary of that valley. Bluff Creek also, which enters the present Rock River a few miles above Byron, has a preglacial course southeastward across the present Rock River to a lower course of the preglacial Leaf River.

The Kishwaukee River, the first important eastern tributary of Rock River south of the Wisconsin line, is in a new course for a few miles below the junction of the north and south branches. It is not clear whether the old mouth was a short distance north of the present mouth or whether the stream passed southward up the south branch to the vicinity of Fielding and thence across to the old Rock River Valley near Esmond. The north and south branches each occupy a preglacial valley for a few miles above their junction, but the headwater portions of each stream are in new valleys. The head of the north fork may not have been so far east as now, for the effect of the ice sheet generally in northern Illinois has been to force streams into the Rock-Illinois drainage basin from the east slope of the limestone ridge which separated this basin from the Lake Michigan Basin.

Kite River, which now flows northwestward into Rock River at Oregon, Illinois, occupies a preglacial western tributary of the old Rock River which may be traced southeastward into the old valley at a point south of Rochelle. The head of the preglacial stream appears to have been in the hills back of the town of Oregon. The present Rock River therefore cuts off only the headwater portion of this preglacial valley.

The preglacial drainage of southern Ogle, northern Lee, and eastern Whiteside counties appears to have been directly toward the preglacial Rock River in southern Lee and northern Bureau counties. The present Rock River intersects several of these streams midway of their course and diverts them westward into the Mississippi. The lower courses of these preglacial streams are now concealed beneath the sand deposits of the Green River Basin. Probably western Whiteside and neighboring portions of Henry and Rock Island counties, now tributary to Rock River, were tributary to a preglacial stream which connected directly with the Mississippi, if they did not themselves discharge directly into the stream.

PRESENT COURSE OF ROCK RIVER.

At the mouth of the Kishwaukee River, 7 miles south of Rockford, Rock River turns directly away from the broad preglacial valley and for 50 miles takes its course southwestward through a much narrower valley (see Pl. XII). The narrow valley extends to western Lee County, a few miles below the city of Dixon. From this point to the Mississippi, a distance of about 80 miles, the river flows in the broad lowland known as the Green River Basin. A few miles above its mouth, however, the basin is interrupted by island-like strips of upland, around which the stream takes its course, as shown in Pl. XVIII. Its main channel is south of the islands, the other channels being occupied only by sloughs and sandy plains.

A somewhat detailed study of the narrow portion of the valley has been made with a view to determining the amount of rock excavation accomplished. This study has brought to light an interesting series of changes in drainage, some of which have already been mentioned. This narrow portion is naturally divided into the following sections, taken in order, beginning at the point of deflection from the preglacial valley and passing

southwestward. The length of each section and estimated amount of rock excavation are also given:

Table showing rock excavation in the new course of Rock River.

	Distance.	Excavation.
	Miles.	*Mile-feet.*
(1) Across a rock ridge	1	15
(2) Up preglacial Bluff Creek	3	100
(3) Across a rock divide	1	30
(4) Down north tributary of preglacial Leaf River	3	60
(5) Up preglacial Leaf River Valley	7	50
(6) Up a south tributary of preglacial Leaf River	3	60
(7) Across a rock divide	2	75
(8) Across Kite River Valley and associated lowlands	7	125
(9) Across a rock divide	2	40
(10) Down a preglacial valley to Green River Basin	20	500
Total	49	1,055

Throughout this narrow portion the stream maintains a width of about 500 feet, but its valley ranges in width from 1,000 feet to fully a mile. The stream makes a descent of only 60 feet, being 680 feet at the mouth of Kishwaukee River and 620 feet at the head of the Sterling rapids, where it opens into the Green River Basin.[1] So far as known, it has no rock rapids in this portion of its course, and there are places where its bed lies 20 feet or more below the low-water level of the stream. The occurrence of these deep places along the river bed and the data obtained from wells along the valley indicate that the rock bottom may generally lie not less than 20 feet lower than the present stream. It has seemed necessary, therefore, in estimating the amount of rock excavation, to assume that it extended to this depth. It may have extended even deeper.

Taking up now the several parts of this narrow section of the river, the following are the data upon which the estimates of the rock excavation accomplished in it have been made:

In the passage across the rock ridge between the preglacial Rock River and Bluff Creek the stream has cut for one-fourth mile at the crest of the ridge to a depth of fully 70 feet and a width of about 1,000 feet, and presents the cross section shown in fig. 6, No. 2, but on the slopes of the

[1] Computed from Greenleaf's Report in Tenth Census, Vol. XVII, 1880.

ridges the rock surface descends to only 20 or 25 feet above the river. The excavation in this ridge is, therefore, not more than 15 mile-feet.[1]

In the three miles along the preglacial Bluff Creek the amount of cutting ranges in depth from 25 to nearly 100 feet and in width from 1,500 to 2,000 feet. The level at which the preglacial stream had cut is marked by a change in the angle of slope (see fig. 6, No. 3), that below being much steeper than that above the preglacial level. It seems safe to assume 100 mile-feet of excavation.

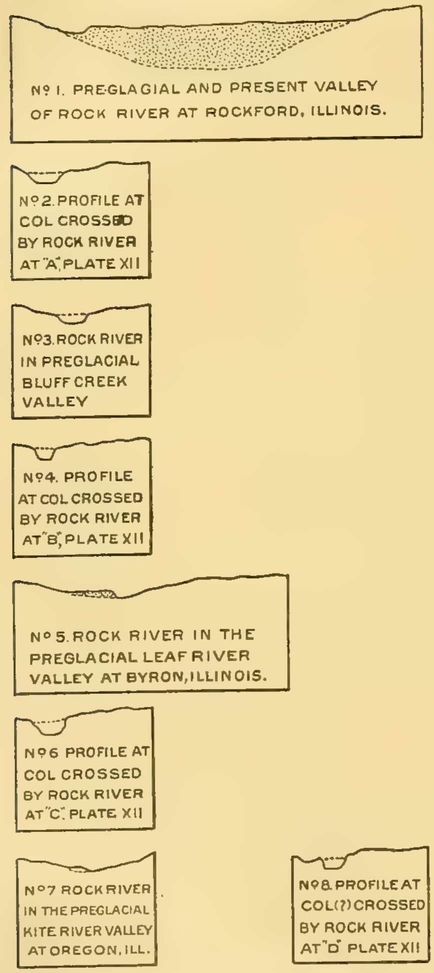

FIG. 6.—Sections across Rock River Valley, in northern Illinois.

On the divide between Bluff Creek and the north tributary of the preglacial Leaf River the cutting is estimated to be double that at the neighboring rock divide on the east, or 30 mile-feet (see fig. 6, No. 4). It has a depth of 80 to 110 feet and a width of 1,200 to 2,000 feet.

Along the north tributary of the preglacial Leaf River the excavation decreases from about 80 feet practically to zero. The width of excavation is about 2,000 feet, widening to nearly 2,500 feet at the border of the old Leaf River Valley. The excavation is estimated to be 60 mile-feet.

In the 7 miles along the preglacial Leaf River Valley the excavation is confined to a slight cutting of perhaps 25 feet at the borders of the preglacial valley, which diminishes to zero before reaching the middle of the valley. The valley here is a mile wide, with gradual rise to either bluff, as shown in fig. 6, No. 5. The excavation is estimated to be but 50 mile-feet, which is proportionately less than along any other part of this narrow portion of the valley.

[1] A mile-foot embraces a block 1 mile square and 1 foot thick.

Along the south tributary of Leaf River the limits of preglacial excavation are clearly marked as on Bluff Creek. The excavation on Rock River increases from 25 feet or less to about 75 feet. The width of this portion of the valley is about 2,000 feet. The excavation is estimated to be 60 mile-feet.

On the divide between the preglacial Leaf and Kite rivers the excavation appears to have ranged from 60 feet up to perhaps 125 feet in depth, and the width is somewhat uniformly about 2,000 feet (see fig. 6, No. 6). The excavation is estimated to be 75 mile-feet.

In the Kite River Valley and associated lowlands the excavation apparently ranged from zero to about 50 feet in depth. In Kite River Valley the width is a mile or more, but below the valley it is about 2,000 feet. An average cross section is shown in fig. 6, No. 7, which is at Oregon. The excavation is estimated to be 125 mile-feet.

South of Kite River the depth of excavation appears to scarcely exceed 50 feet, and no sharply defined col could be found, for, being in the St. Peter sandstone area, the uplands are very uneven. The width of excavation is 2,000 to 2,500 feet, and the total excavation is estimated to be only 40 mile-feet. The profile shown in fig. 6, No. 8, is found at D, Pl. XII, and may perhaps cross at the site of an old col.

The depth of excavation along the portion of Rock River between the place shown in this profile and the Green River Basin has not been so carefully computed as in the portions above. The river appears to follow the line of a small preglacial stream as far as the mouth of Pine Creek, whose valley has been somewhat broadened by it. Below the mouth of Pine Creek the preglacial valley has been widened but little. The average width of the valley is about one-fourth mile, and in places it reaches nearly a mile. Such is the case at the sharp bend at Grand de Tour and at bends near Dixon. The rock excavation may possibly amount to 500 mile-feet in this lower 20 miles, but it seems as probable that it does not exceed 400 mile-feet, and it may be even less.

Combining the above estimates, it appears that there has been not more than 1,055 mile-feet of excavation in the 49 miles of this narrow section of the Rock River Valley, and possibly it falls below 1,000 mile-feet. It may, therefore, be roughly placed at one-fifth of a cubic mile. The present discharge through this valley, based upon estimates by Greenleaf and by Rae, is somewhat more than 4,000 cubic feet per second, that being

the estimated average yearly flow past the city of Rockford.[1] It is not known whether the present flow differs widely from that of the stream which produced this rock excavation, for the excavation appears to have been practically completed prior to the Wisconsin stage of glaciation. The drainage area and the rate of discharge may have been altered somewhat as a result of the Wisconsin invasion. Also a part of the rock cutting may have been produced by a glacial stream at the time of deflection. It is thought, however, that the glacial stream would have expended its energies at the rock divides, and that changes in drainage area are of minor consequence, so that the excavation may be assumed to have been chiefly accomplished by a stream similar in size to the present Rock River.

This narrow section of the Rock River Valley carries deposits of glacial gravel which appear to be the continuation of the broad gravel plain that leads down the preglacial Rock River Valley from the Kettle moraine of the Green Bay lobe. This gravel plain stands about 50 feet above the present level of Rock River at Rockford and southward from that city to the point where the preglacial and present valleys of Rock River part company. It has no continuation southward along the preglacial valley, but passes instead down the narrow valley of the present stream. Its altitude at Byron, as shown by the railway survey, is 50 to 55 feet above the low-water level of the stream at that point. At Oregon its elevation is about 40 feet, and it maintains an elevation of nearly 40 feet from there to the point where it emerges into the Green River Basin above Sterling. This filling apparently began a few feet below the present river level, since the wells made along the flood plain encounter gravel to a depth of 10 to 20 feet or more below the stream. However, in places on the borders of the valley it rests upon rock at a level slightly above the present stream. It may not, therefore, amount to more than would be necessary to build the valley up from its present level to a height of 50 feet. Assuming this to be the case, the filling will equal about four-fifths of the amount of rock removed from the channel prior to its deposition, or to about 0.16 of a cubic mile. The amount deposited in the 50 miles embraced in the section of the preglacial valley between the Kettle moraine and the head of this narrow section is much greater. It is at least 50 feet and may amount to 75 feet in depth. The width being 2½ miles or more, it follows that

[1] Seventeenth Ann. Rept. U. S. Geol. Survey, Part II, 1896, pp. 733, 734.

there was not less than a cubic mile deposited in this section of the preglacial valley, and the amount may possibly approach 2 cubic miles.

The amount of excavation accomplished since the deposition of the gravel is remarkably small. The valley formed subsequent to this gravel deposition varies but little in breadth in the 100 miles from the Kettle moraine to the lower end of the narrow section. It is usually about 1,500 feet in width, and seldom exceeds 2,500 feet. Its flood plain is 30 to 40 feet below the level of the gravel plain and its stream bed about 50 feet. The stream occupies about one-third the width of this postglacial valley. The amount of excavation accomplished in the narrow section under discussion is estimated to be about 650 mile-feet, or slightly more than half the amount of rock excavation accomplished prior to the deposition of the Wisconsin gravel.

It is a matter of much interest to ascertain the relative lengths of time involved in the interglacial rock excavation and the postglacial gravel excavation. This, however, must be left to more refined methods than are now at command. It seems safe to assert that the time involved in the rock excavation was longer than that involved in the gravel excavation, though it must be borne in mind that water may find passage through or over gravel without disturbing it, where it might be cutting rapidly in the soft St. Peters sandstone which forms a portion of the new channel of Rock River. But the greater part of the rock excavation has been in limestone, which would perhaps offer fully as much resistance to erosion as the gravel deposits which now line the valley.

The deflection of Rock River into this new course certainly preceded the Wisconsin stage of glaciation, and probably preceded the Iowan. The completeness of the removal of rock barriers along its new course and the general character of the channeling seem to ally it with certain rock gorges found in portions of northwestern Illinois and southern Wisconsin, west of Rock River, which, as determined by Hershey, were largely excavated prior to the Iowan stage of glaciation.[1] These gorges are discussed below and their relation to the Iowan deposits are set forth. Furthermore, the work accomplished elsewhere between the Iowan and Wisconsin stages of glaciation throws doubt upon the view that this channel was entirely excavated after the Iowan stage of glaciation. The work involved in the

[1] Pleistocene rock gorges of northwestern Illinois, by Oscar H. Hershey: Am. Geologist, Vol. XII, 1893, pp. 314–323.

channeling, therefore, seems referable mainly to the interval preceding the Iowan glaciation, and only in small part to that succeeding it.

An instance of a rock gorge formed subsequent to the Iowan stage of glaciation is found in the west part of the city of Rockford, where Kent Creek enters Rock River over a series of cascades. The stage of excavation here is far less mature than in the rock gorges which were opened between the Illinoian and Iowan stages or in the new course of the Rock River under discussion.

Concerning the lower portion of the new course of Rock River, between the city of Sterling and the mouth of the stream, a few words seem necessary. The river enters the sandy plain known as the Green River Basin near the city of Sterling, a plain which stands but 25 to 40 feet above the stream. In the 80 miles from Sterling to its mouth the river makes a descent of 84 feet, of which 15 feet occur in passing the rapids at that city, and about 25 feet more in the 18 miles between Sterling and Lyndon. The average descent, including the rapids, is about 1 foot to the mile, or nearly the same rate as in the narrow portion of its course in the 50 miles above Sterling. This lower portion of the stream is evidently independent of preglacial lines, for it frequently encounters rock ledges, and its bed is entirely floored with rock for several miles in the vicinity of its mouth. The Green River Basin has apparently been deeply filled with drift, so that the stream encounters rock only in its passage across preglacial interfluvial tracts. It seems probable that the preglacial channels in this basin reach a level 100 feet or more below the interfluvial tracts, or sufficiently low to correspond with the rock bottom of the preglacial Rock and Mississippi rivers in neighboring districts.

Much of the erosion accomplished by Rock River in the Green River Basin has occurred since the Wisconsin stage of glaciation, for a large part of the surface gravel and sand in which the stream has its channel appears to be an outwash from a moraine of Wisconsin age at the head of the basin. The size of the valley, moreover, corresponds to that of the post-Wisconsin Valley in the upper portion of the stream. The rapids at Sterling also ally it with gorges opened since the Iowan, and are consistent with a post-Wisconsin age.

GREEN RIVER.

The headwaters of this eastern tributary of Rock River are found in the elevated moraine forming the border of the Wisconsin drift in southeastern Lee County, Illinois, and standing 950 to 1,000 feet above tide.

The several headwater streams descend rapidly to the sandy plain outside the moraine. They there soon enter a wet prairie—"Inlet Swamp"—whose altitude is about 775 feet above tide and which covers perhaps 16 square miles. No channel is maintained across this prairie, but from the west end of the prairie a stream with a well-defined channel leads westward about 15 miles to another wet prairie—"Winnebago Swamp"—making a descent of nearly 100 feet. In this second wet prairie, which is fully 10 miles in length, the stream has only a poorly-defined channel, but apparently makes a descent of several feet. The western part of the prairie is estimated by Rolfe to stand only 660 feet above tide. In the next 25 miles, to the crossing of the Bureau-Henry county line, the stream has a poorly-defined channel, meandering about through a series of marshes among sand hills, but making a descent of 60 feet (Rolfe). In the remaining 35 or 40 miles to its mouth the stream falls about 40 feet and maintains a well-defined channel. In the lower 18 or 20 miles (below Geneseo) it has excavated a valley fully 20 feet in average depth and nearly one-half mile in width. In this section of its course it is bordered by uplands which are far less sandy than the lowland plain known as the Green River Basin.

The sand which covers the Green River Basin, as previously indicated, appears to be largely an outwash from the Wisconsin moraine. The channel of Green River is, therefore, of post-Wisconsin age, although traversing a district which stood outside the limits of the ice sheet at the Wisconsin stage of glaciation. The trench which it has cut below Geneseo is entirely in deposits of silt which are also of apparently Wisconsin age. They have an elevation corresponding closely to that of the Wisconsin terrace on neighboring portions of the Mississippi, and it is thought that they are slack-water deposits connected with the swollen Mississippi during the time in which it was building up the terrace.

ROCK GORGES OF NORTHWESTERN ILLINOIS.

In the portion of northwestern Illinois lying between Rock River and the border of the Driftless Area the drift is generally so thin that the streams follow in large part the preglacial lines. There are, however, several instances of the deflection of streams into the edge of the bluff or across a projecting point on the border of a valley. Such deflections usually occur where a cluster of knolls or ridges of drift greatly obstruct the valley, and they are usually only of sufficient length to pass the obstruction. In some

cases, however, the stream is thrown across the divide into another preglacial valley. The streams in cutting new courses through the rock ledges have found the material so resistant that very narrow channels have been formed which, because of their narrowness and the precipitous rock cliffs on their borders, are known as rock gorges. Several of these rock gorges in Stephenson County have been examined with considerable care and discussed by Hershey.[1] His paper contains the following table of measurements and estimates of a few of these gorges. There is added a more recent measurement of a gorge on Carroll Creek just west of Mount Carroll:

Measurements of rock gorges in northwestern Illinois, by Oscar H. Hershey.

No.	Situation.	Drainage area.	Length.	Breadth.	Depth.	Cubic contents.	Width of bottom.	Width of present stream.	Ratio width of bottom to width of stream.
		Sq. miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*	*Feet.*	*Feet.*	
1	1 mile north of Freeport.	½	950	140	29	140,000	50	5	10 : 1
2	5 miles northwest of Freeport.	4	850	240	44	330,000	175	25	7 : 1
3	3 miles south of Freeport.	10	2,050	235	36	640,000	200	20	10 : 1
4	Cedarville	29	3,250	160	57	1,100,000	133	25	5.3 : 1
5	Cedarville	1½	225	175	15	21,875	150	5	30 : 1
6	3 miles west of Freeport.	1	950	100	25	88,000	80	8	10 : 1
7	4 miles west of Freeport.	5	1,100	165	30	202,000	145	10	14.5 : 1
8	Carroll Creek	45	2 miles.	180+	50	3,530,000	180	30	6 : 1

From the above table it appears that the gorges show remarkable variations in size, the causes for which are not made clear. The small ratio of width of bottom to width of stream displayed by the two streams having the largest drainage area raises the suspicion that the smaller streams may have had softer material to work upon and thus have been able to accomplish a greater amount of excavation than that displayed by the two larger streams. The writer has had opportunity to examine only two of the gorges, No. 1 and No. 8 of the above table. These gorges are of somewhat different type. The gorge No. 1, on the small stream north of Freeport, has bluffs so broken down that an ascent may easily be made at almost any point. As shown in the table, the top of the gorge has a breadth nearly three times as great as at the bottom, though the gorge is scarcely 30 feet

[1] Pleistocene rock gorges of northwestern Illinois, by Oscar H. Hershey: Am. Geologist, Vol. XII, 1893, pp. 314–323.

in depth. But gorge No. 8, on Carroll Creek, has precipitous bluffs which are often perpendicular and in places overhanging, so that the bottom width is nearly as great as the top except where the gorge is cut largely in drift; it there presents gradual slopes. Hershey's measurements of the gorge at Cedarville (No. 4 of the table) indicate that it may be about as abrupt as the gorge on Carroll Creek. He considers the Cedarville gorge the best illustration found in Stephenson County, and has presented the following description of it.[1]

The Cedarville gorge (No. 4 of the table) may be taken as the type, and a description of it will apply, with some modifications, to all the others. Cedar Creek, situated in the central part of Stephenson County, flows in a general southwest direction into Richland Creek. After traversing a broad valley, with gently sloping sides covered with drift and loess, it suddenly enters a deep, narrow gorge with steep, rock-bound walls. The contraction of the valley from 3,000 to 160 feet is conspicuous and readily attracts attention. The old valley can be traced around by the south, but is partially filled with sand ridges. The sides of the gorge are in some places perpendicular. They generally slope at an angle of about 30 degrees. The bottom is flat and consists of a bed of dark-brown alluvium, through which the stream meanders, sometimes touching one side and sometimes the other, undermining the walls and widening the valley. After about three-fifths of a mile the stream enters a small preglacial valley and the gorge widens, but the same canyon-like character prevails to its end. A small tributary occupies a portion of the old valley, and when Cedar Creek again enters this valley the significant fact is learned that a stream one-tenth as large as the main creek flows in a valley ten times as large.

Hershey has determined that a large part of the erosion of these gorges, estimated to be at least four-fifths, occurred prior to the deposition of the loess associated with the Iowan drift sheet. The principal line of evidence is found in the occurrence of loess within the gorges near their bottoms. In one case near Freeport a gorge was abandoned because of the large amount of loess filling, and the postloessial stream took a new course. The character of the evidence is such that the conclusions drawn by Hershey seem fully sustained. Within the limits of the Iowan drift in northwestern Illinois there are several instances of the initiation of a new course for the stream at the close of the Iowan stage of glaciation. The channels cut by streams having this date are so much smaller than the rock gorges included in the above table that it is not difficult to separate the two classes of valleys. In the gorges under discussion the streams not only flow in valleys having bottoms several times as wide as the stream beds, but so far as known they are entirely free from falls or rock rapids. But in the streams which

[1] Loc. cit., p. 316.

have opened new courses since the close of the Iowan stage of glaciation it is the rule to find rock rapids, and even low falls.

Hershey devotes a considerable part of his paper to the discussion of the comparative amount of erosion in these valleys and those opened at the Iowan and Wisconsin stages of glaciation, and concludes that the time required in their excavation is several times that of the Iowan as well as of the Wisconsin.

Rock gorges occur to some extent along the valleys of western Illinois south of Rock River, but they are not of a class similar to those of northwestern Illinois just discussed. They occur usually where streams are opening a course entirely independent of preglacial valleys, and where after cutting through the entire depth of drift they have begun the excavation of the rock. These valleys often have rocky rapids and low falls. It is difficult to compare the amount of work accomplished by these streams with that accomplished by the streams of northwestern Illinois. The streams of western Illinois have had usually a large amount of drift to remove, and consequently have been prevented from beginning the excavation of the rock at so early a date as was possible for streams in northwestern Illinois. The valleys which they have excavated in the drift show much greater cubic contents than the rock gorges of similar sized streams of northwestern Illinois. It remains to be determined whether the work accomplished in removing the drift deposits is sufficient to offset the immature state of development on the rock gorges, or whether the excavation of the rock gorges of the two districts began at different dates. In western Illinois the excavation may confidently be placed after the Illinoian ice invasion, but in northwestern Illinois the possibility of deflection by a pre-Illinoian invasion must be considered.

ILLINOIS RIVER DRAINAGE BASIN.

The watershed of the Illinois River extends in a broad band, averaging 100 miles in width, in a northeast-southwest direction directly across the center of Illinois. From the northeastern extremity of this band there are two projections—one north into Wisconsin, including the Fox and Des Plaines basin; the other east into Indiana, including the Kankakee and its main tributary, the Iroquois. The name Illinois is applied to the river from the junction of the Kankakee and Des Plaines. The western side of the watershed is 20 to 40 miles in width, while the eastern is 60 to 80 miles. The entire area is estimated by Greenleaf, in his report for the Tenth Census,

to be about 29,000 square miles. An estimate made by L. E. Cooley, of the Chicago Drainage Commission, reduces it to 27,914 square miles. The area in each of the three States is estimated by Greenleaf to be as follows: Illinois, 24,726 square miles; Wisconsin, 1,080 square miles; Indiana, 3,207 square miles. The drainage areas of the tributaries given in order from source to mouth, as estimated by Cooley, are as follows:[1]

Drainage areas of tributaries of Illinois River.

	Square miles.
Des Plaines River	1,392
Kankakee River	5,146
Aux Sable Creek	218
Mazon Creek	540
Fox River	2,700
Covel Creek	100
Vermilion River	1,317
Pecumsaugum Creek and Little Vermilion River	165
Bureau Creek	480
Sandy Creek	147
Crow Creek (east)	226
Senachwine Creek (south)	132
Kickapoo Creek	310
Mackinaw River	1,217
Copperas Creek	151
Quiver River	220
Spoon River	1,870
Sangamon River	5,670
Sugar Creek	180
Crooked Creek	1,385
Indian Creek	290
McKees Creek	472
Mauvaise Terre Creek	275
Big Sandy Creek, etc	525
Macoupin Creek	985
Total	26,303
Total area of Illinois watershed	27,914
Area of small tributaries and slopes	1,611

Of the 27 tributaries included in the above table, it will be observed that 13 carry 23,699 square miles, or about 85 per cent, of the drainage of the Illinois Basin. There are, in addition to the tributaries above given, 20 more which are sufficiently large to have received names, but which have a combined drainage area of only 1,300 square miles. The remaining 300 square miles are comprised in the slopes of the Illinois River Valley and the insignificant tributaries.

[1] Rept. Illinois State Board of Health, 1889, p. 68.

The Illinois River, as far down as Peoria, has its course through a district covered by drift of Wisconsin age. Below that city as far as southern Pike County, its bordering uplands are coated with Illinoian drift, and this is capped by loess. From Pike County southward the uplands on the west are nearly free from glacial drift, but are heavily coated with loess. Those on the east have a moderate amount of Illinoian drift capped by loess.

Much of the Kankakee Basin and the headwater portion of Fox River afford very imperfect drainage and contain extensive marshes. They also contain small lakes and marshy shallow lakes, as well as the wet marshy prairies. Elsewhere within the limits of the Wisconsin drift the marshes, bogs, and lakes connected with the Illinois River drainage are of small extent, but there is, on the whole, a rather imperfect development of drainage lines. Often areas of several square miles, and occasionally entire townships, are without a well-defined channel for the discharge of water. It is only by a judicious system of ditching, including both surface ditches and tile drains, that this area has been brought into its present fair condition for cultivation. Much still remains to be done before the full resources of the rich soil will be at command.

Within the portion of the drainage basin in which loess forms the surface and Illinoian drift the substratum the drainage is markedly better developed than within the portion covered by Wisconsin drift. Swamps or marshes are of very limited extent, but there are not a few swales or shallow valleys which are poorly drained. Tile draining is found very advantageous on the level portions of the uplands, and the drains are often continued along the shallow valleys or swales into the well-defined valleys.

The Illinois Valley is naturally divided into two parts, the upper and lower Illinois. The upper Illinois comprises the westward-flowing portion from the junction of the Des Plaines and Kankakee down to the bend near Hennepin, a distance of about 50 miles; the lower comprises the southward-flowing portion extending from Hennepin to the mouth, a distance of about 200 miles. The upper Illinois is excavating a new course and its bed is usually on the rock, while the lower Illinois occupies a preglacial channel in which the rock bottom lies nearly 100 feet below the bed of the present stream. This preglacial channel, as above indicated, con-

stitutes the southward continuation of the preglacial channel occupied by Rock River in southern Wisconsin and northern Illinois.

THE LOWER ILLINOIS.

The lower Illinois Valley, as indicated above, seems to have been so imperfectly filled by glacial deposits that throughout nearly its entire length the stream is reestablished in the old course. The portion below the mouth of the Sangamon River has been filled to a level less than 100 feet above the present stream. The portion above the mouth of the Sangamon has evidently been filled to irregular heights, as shown by terraces in the valley and on its tributaries. The greatest filling seems to have been at Peoria, where the Shelbyville moraine crosses. Terraces of tributary streams here indicate a filling of not less than 170 feet above the present river level. Portions of the valley above Peoria seem to have been filled to scarcely 100 feet above the stream, while the filling below Peoria declines rapidly to a level 100 feet or less above the stream. The preglacial tributaries leading into the lower Illinois are more completely filled than the main valley. As far down as the mouth of the Sangamon it is impossible to trace the courses of eastern tributaries, so complete has been the filling, and below the mouth of that stream the tributary valleys are traceable for only a few miles in the lower courses of the present streams. The western tributaries, as shown below, may be traced in several instances some distance back from the main valley.

The valley of the lower Illinois ranges in width from 2½ to fully 15 miles. Its greatest expansion is just above the mouth of the Sangamon, and the full width of the preglacial valley at this point is not known. The sandy bottoms have a breadth of 12 to 15 miles, but the uplands to the east are filled with drift which extends far below the level of the river bottoms, as shown by numerous well sections. The valley is also broad in the vicinity of the bend of the Illinois. The sandy and gravelly bottoms have a width of 6 or 8 miles, and the preglacial valley has still greater width.

The narrowest portions of the lower Illinois Valley are a short section at the city of Peoria, where it passes through the Shelbyville morainic system, and a section embracing the lower 60 miles, where it traverses the Eocarboniferous and Silurian limestones. The reduced width near the

mouth of the stream is in all probability due to the hardness of the formation excavated. It is not so certain that the construction at Peoria is due to the same cause. Indeed, there is a possibility that the stream here has been deflected across a projecting point of the west bluff. The existence of a broader channel to the east, however, has not been demonstrated.

Several borings have been made along this preglacial valley, and they present variations in the altitude of the rock bottom which are somewhat perplexing. The borings in the vicinity of the bend of the Illinois at Peru, Princeton, and Bureau Junction show a rock bottom only 325 to 340 feet above tide.[1] Below this bend the rock bottom is usually encountered at a slightly higher elevation. The majority of the wells are located within a mile of the bluff of the preglacial valley, which might perhaps signify that the deepest part of the channel had not been struck. But wells at Beardstown, in the midst of the valley, enter rock at a level as high as at the bend of the Illinois, 125 miles up the valley. Bridge foundations near the mouth of the Missouri and at St. Louis, 103 and 128 miles, respectively, below Beardstown, show the rock bottom to descend to a level slightly less than 300 feet above tide, or about 50 feet lower than at Beardstown and at the bend of the Illinois. It is barely possible that these bridge foundations have not extended out to the deepest part of the channel, but it seems scarcely probable that the floor has a much lower level in the middle of the channel. The amount of descent below Beardstown is not remarkably low, but in the 134 miles from Princeton to Beardstown there appears to be no descent.

This suggests the query whether there may not have been a differential northward depression in the portion of the Illinois Valley north from Beardstown. To fully establish this depression, it will be necessary to make certain that there is no deeper portion of the valley leading past Beardstown and other points in the lower course of the stream. In view of the possibility of northward depression, it seems pertinent to refer to a possible cause for such a depression. To the general cause for northward

[1] In a paper published in the Journal of Geology (Vol. III, 1895) the writer called attention to a boring at Princeton, Illinois, which was reported to have penetrated 440 feet of drift and to have entered rock at 270 feet above tide. A subsequent boring, only a few feet distant, entered rock at 370 feet, but passed through a soft shale between 370 and 440 feet. It is now thought that the well first made may also have entered this shale at a depth of about 370 feet, or an elevation 340 feet above tide.

depression, found in the weight of the ice sheet, an additional cause is here found in the great amount of drift deposited along the course of the old valley. This valley from the vicinity of Pekin northward is filled, as well as bordered, by heavy deposits of drift, which are rarely less than 200 feet in depth and which reach a probable maximum of between 500 and 600 feet in the district north of Princeton, where the moraine occupies the old valley. This weight of drift, unlike that of the ice sheet, still continues to be an obstacle to the return of the valley floor to its former altitude, if not a direct cause of depression. Possibly it even now is causing a depression of that region, and the low gradient of this portion of the Illinois may perhaps be explained in part by such a depression.

In the following table the available data concerning the altitude of the rock floor compared with the present Illinois are presented:

Altitudes of rock floor and present lower Illinois River.

Location.	Distance.	Low water (above tide).	Rock floor (above tide).
	Miles.	*Feet.*	*Feet.*
Princeton (abandoned channel)	0	....	340
Bureau Junction (Bureau Creek Valley)	9	....	340
Hennepin	4	*a*438	380
Putnam	7	438	340
Henry	6	438	355
Peoria (Brigham's well)	34	429	341
Pekin (city well)	11	427.3	325
Beardstown	63	418.6	345
Mouth of Illinois	86	403.6	(?)
Bellefontaine, Mo. (bridge)	17	402±	295
East St. Louis, Ill. (bridge)	25	380	284

a A dam located at Henry, Illinois, raises the river to 438.1 feet. The altitudes at points below Henry are given at the natural level of the river.

THE UPPER ILLINOIS.

In the 41 miles from the junction of the Des Plaines and Kankakee down to Utica, where apparently a small preglacial tributary of the Illinois is entered, the course of the present Illinois is independent of preglacial drainage lines. About midway of its westward course it crosses the Marseilles moraine. This no doubt for a considerable period held a lake in the basin at the head of the river (the Morris Basin), but was eventually cut down to the level of the low part of this basin. From the Marseilles

moraine westward the channel found no prominent drift barriers to remove, but has been compelled to cut down 50 to 75 feet into the rock in opening an outlet from the Morris Basin into the valley of the lower Illinois.

In the 41 miles to the foot of the rapids near Utica the stream falls 47 feet, or slightly more than 1 foot to the mile. This fall is far from regular, there being a series of rock rapids separated by pools. The following table of variations is based upon data published by Cooley.[1] In the first mile a fall of 44 inches is made, after which for nearly 12 miles the fall is less than 4 inches to the mile, and in the next 12 miles is but 8½ inches to the mile (if the Marseilles dam were removed). This portion apparently crosses lines of preglacial valleys, for wells indicate that the drift extends in places 50 to 60 feet below the river level. Near Marseilles a fall of 10 feet is made in about 1½ miles, below which for over 5 miles a rate of fall is continued which averages about 2 feet to the mile. The rate then decreases to less than 6 inches to the mile. This is maintained for 6.7 miles. Another rapid is then passed, with a fall of 6.8 feet in 2.6 miles, when a pool is reached, near Utica, that is formed by the dam at Henry, 20 miles below. The above conditions are set forth in the following table:

Table showing variations in bed of upper Illinois River.

Location.	Distance.	Low water (above tide).	Fall per mile.
	Miles.	*Feet.*	*Inches.*
Mouth of Kankakee River	0	485.3	....
One mile below	1	481.6	44.04
Head of Marseilles pool	11.7	477.9	3.80
Marseilles, below dam	12.7	468.8	8.59
Foot of Marseilles rapids	1.5	458.3	84.00
Mouth of Fox River	5.3	447.9	23.54
Head of rapids	6.7	444.9	5.37
Foot of rapids near Utica	2.6	438.1	31.38

This portion of the Illinois Valley, although of post-Wisconsin age, has a channel more than a mile in average width and nearly 100 feet in average depth. Yet at present it is the line of discharge for an area of only 12,000 square miles. The influence of the waters discharged from

[1] Lake and Gulf Waterway, by L. E. Cooley, 1890.

Lake Chicago, and also from the ice lobes north and east of the Kankakee, is plainly shown in the great size of this valley, as has been pointed out on preceding pages.

DES PLAINES RIVER.

The Des Plaines River drains a narrow strip extending north to south a distance of 90 miles, from Kenosha County, Wisconsin, to the head of the Illinois in eastern Grundy County, Illinois. The greatest width of the watershed is scarcely 25 miles. The area, as above noted, is 1,392 square miles. Aside from the Des Plaines River there are only four noteworthy tributaries—Dupage River, Jackson Creek, Hickory Creek, and Salt Creek.

The portion of the Des Plaines watershed north from the Chicago Outlet falls within the low area bordering Lake Michigan inside the Valparaiso morainic system. It still discharges into the lake at flood stages through a portion of the old outlet known as "Mud Lake" and South Chicago River. It is thought by Cooley and by others familiar with the ground, including the present writer, that the entire discharge may, until within a few hundred years, have been into the lake instead of down the Chicago Outlet. The divide between Mud Lake and Chicago River is a flat silt-covered tract situated near Kedzie avenue, in Chicago. The south branch of Chicago River has a channel with a capacity proportioned to such a stream as the Des Plaines, and the bed of Mud Lake bears evidence of being the line of discharge from the Des Plaines to the Chicago River. Furthermore, the portion of the Des Plaines Valley below Summit (where Mud Lake leads off from the Des Plaines) carries only a poorly defined channel a foot or two in depth. Cooley remarks: "Had the Des Plaines gone southward ever since the abandonment of the ancient outlet, it would ere this have grooved itself in the rock, built up its banks, and reduced the prism of Lake Joliet to present requirements."[1] The cause for the deflection into the old lake outlet is supposed to be a silting up of the Mud Lake channel. This matter, however, has not been carefully investigated by the writer. Cooley remarks concerning this diversion:

> There are many ways in which the long flat divide at Kedzie avenue could have been built up, and we believe there is a tradition that the beaver was concerned in the matter. In any event, the work once initiated, natural silting would carry it on until the waters were turned out across the old pass.[2]

[1] See report of Illinois State Board of Health, 1889, pp. 54, 55, 69–75.

[2] Op. cit., p. 71.

By this interpretation the Dupage and other tributaries of the lower Des Plaines, as well as the portion of the Des Plaines itself outside the Valparaiso morainic system, should be referred to a distinct drainage basin from that of the upper Des Plaines. The upper Des Plaines, as above defined, has an area of 524 square miles and a length of 62 miles (Cooley). If Salt Creek be included, the area is 634 square miles. At the source of the Des Plaines is a slough which drains northward to Root River, a tributary of Lake Michigan entering at Racine, Wisconsin, as well as southward to the Des Plaines, and which stands 112 feet above Lake Michigan (Cooley). The course of the upper Des Plaines is governed by till ridges on its east border, as indicated above, except for a few miles near its entrance into the Chicago Outlet. It there traverses a southward-sloping plain.

The course of Salt Creek also is governed by a till ridge on its east border as far south as Fullersburg. It there turns east through a gap in the ridge, but its old course was southward past Western Springs, through Flag Creek Valley, to the Chicago Outlet near Willow Springs. Its old valley is larger than the new one, from which it is inferred that the deflection is somewhat recent. The cause for the deflection is perhaps a silting up at the mouth which followed the abandonment of the lake outlet. Conditions for such silting are favorable, for there is scarcely any fall along the bed of the outlet for several miles below the old mouth of the creek. This interpretation, however, is one which has not been fully tested by observations in the field.

For 30 miles below the point where the Des Plaines enters the Chicago Outlet it traverses the Valparaiso morainic system and receives no tributaries of importance, for much of the drainage there is only the bluff drainage. It has not in this interval perceptibly modified the bed of the old lake outlet. There is the "12-mile level" below Summit, soon followed by the descent of about 70 feet in 8 miles. Farther down are two pools—one below Joliet, known as Lake Joliet, another near the mouth of Dupage River, known as Lake Dupage—which are separated by an interval of 3 miles of slope with a fall of about 13 feet. There is also a fall of about 2½ feet in the half mile from Lake Dupage to the junction with the Kankakee at the head of the Illinois. The only true flood-plain bottoms are in the 7 miles between Lake Joliet and the head of the Illinois. These lie within the range of backwater from the Kankakee and are overflowed only in case of

floods from that stream (Cooley). These flood plains have been built up by overflow to about the average high-water level.

At Joliet an eastern tributary—Hickory Creek—having a watershed of 130 square miles, enters the valley and forms a limited area of flood plain in its delta. Its source is in the midst of the Valparaiso moraine. Another eastern tributary—Jackson Creek—having a watershed of about 86 square miles, enters nearly opposite the mouth of the Dupage and helps to swell the lower Des Plaines. This stream heads in the main belt of the Valparaiso system and passes through the outer ridge of that system just north of Elwood.

The Dupage River, which enters only 4 miles above the junction of the Des Plaines with the Kankakee, has a watershed of about 366 square miles. It drains the plain lying between the Minooka till ridge and the Valparaiso morainic system. Its east branch for a few miles flows southward between the outer ridge and the main moraine of the Valparaiso system, but passes westward through a gap in this ridge before uniting with the west branch.

The old lake outlet down the Des Plaines, the channels connecting the Des Plaines with the lower Dupage, and the gravel terraces on each stream, have received attention on preceding pages.

KANKAKEE RIVER.

The Kankakee River, which unites with the Des Plaines to form the Illinois, drains an estimated area of 5,146 square miles, of which 3,040 square miles lie in Indiana and the remainder in Illinois. The general trend of its watershed is east to west, and the extreme length is about 200 miles. The greatest width from north to south is about 70 miles.

The watershed has its northern limits in the Valparaiso morainic system, and all the important northern tributaries find their sources in this morainic system. Its southern limits in the portion below the mouth of the Iroquois are found in the Marseilles moraine. The Iroquois is a somewhat distinct watershed, draining basins south of the Iroquois and Marseilles moraines and passing through a gap in the Marseilles moraine to enter the Kankakee. There is no well-defined ridge separating its watershed from the Wabash watershed. The eastern limits of the Kankakee watershed are mainly in the Maxinkuckee moraine of the Saginaw lobe, but Yellow River drains a

small tract lying east of the moraine. As above noted, the Kankakee formerly constituted the line of discharge for the St. Joseph River, now tributary to Lake Michigan, and it is probable that it carried also a large amount of glacial drainage from the Saginaw and Lake Michigan lobes (see Pl. XV).

With the exception of the somewhat distinct watersheds of the Iroquois and Yellow rivers, the Kankakee area constitutes a single great basin, having only small tributaries leading directly from the rim to the river or marsh. The Kankakee marsh embraces probably 1,000 square miles, or about one-fifth of the watershed. In addition to this, about 3,000 square miles have very poor drainage. The best-drained portions are on the Valparaiso moraine and the plains in Illinois between the Valparaiso and Marseilles moraines. These, however, are poorly supplied with channels for discharge, and much ditching and tile draining have been found necessary. The head of the Kankakee marsh near South Bend, Indiana, stands about 140 feet above Lake Michigan, or 720 feet above tide. From this point to Momence, Illinois, a distance of 82 miles by direct line, there is a continuous marsh which has a somewhat uniform descent of about 15 inches to the mile, its altitude at Momence being 104 feet lower than at South Bend. The windings of the stream are reported by Cooley to increase its length to about 250 miles, and thus to reduce the fall to only 5 inches to the mile. The amount of water above the junction with Yellow River is insufficient to form a well-defined channel, but below that point there is quite a definite open channel. The small tributaries are usually lost in the marsh before reaching the main stream. The Kankakee Valley Drainage Company has estimated that 625 square miles may be directly reclaimed and 1,000 square miles benefited by systematic ditching.[1]

At Momence occurs the first limestone outcrop in the bed of the river. In the 14 miles below Momence to the junction with the Iroquois there is a rock bed and a fall of 25 feet. In the 33½ miles from the mouth of the Iroquois to the head of the Illinois the Kankakee falls 103 feet, or an average of 3 feet to the mile. There are rapids near Altorf and at Wilmington, each of which have a descent of about 20 feet. The inner valley is but little wider than the stream, and has a depth of only 15 feet at Momence, 25 feet at Kankakee, and about 35 feet in western Kankakee and

[1] See official report to governor of Indiana, 1882.

southern Will counties, though at a few points it approaches 50 feet. Outside of this, as previously described, there is a broad bottom, averaging about 2 miles in width, which has a low bluff of till along the north border, rising 15 to 25 feet or more above it. But on the south there are sandy ridges and knolls which seldom present a definite bluff line.[1]

Yellow River has a drainage area of about 700 square miles, of which probably 500 square miles are within the limits of the Maxinkuckee moraine of the Saginaw lobe and outside the region under discussion. This portion on the Saginaw drift is widely branching and drains the greater part of Marshall County, together with small parts of St. Joseph, Elkhart, and Kosciusko counties. The portion west of the Maxinkuckee moraine consists mainly of its immediate channel and the outlet of Twin Lakes, its course being through a sand-covered district in which the drainage is very imperfect. None of this watershed can be considered well drained, although the headwater portion resembles the neighboring portions of northern Indiana, which, like it, are under cultivation. The soil, being a sandy loam, requires less perfect surface drainage than clay soils, such as characterize the drift of the Illinois lobe.

The Iroquois River has a watershed of about 2,000 square miles, though much of this watershed is very imperfectly drained by it. Fully 800 square miles, or nearly one-half, lies in Indiana. At Watseka the river receives its principal tributary—Sugar Creek. Below Watseka are three noteworthy tributaries—Spring Creek, Langum Creek, and Beaver Creek. In its passage through the Marseilles moraine in the lower 5 miles of its course considerable descent is made, but elsewhere the stream is generally sluggish, and so are the tributaries.

The west-flowing portion of the Iroquois drains a large sandy area in Indiana south of the Iroquois moraine. It passes through that moraine before reaching Watseka. Sugar Creek drains the outer face of the Iroquois moraine in the portion southeast from Watseka, while Beaver Creek furnishes the chief drainage for the outer face northwest from Watseka. The basin in Iroquois County, south of the Marseilles moraine,

[1] Many data concerning the Kankakee Basin have been collected by Prof. L. E. Cooley and presented in a paper contained in the Report of the Illinois State Board of Health, 1889. The writer is indebted to this report for many of the statistics above presented, as well as for those of the Iroquois and Yellow rivers, presented below.

has rather imperfect drainage through the several tributaries of the Iroquois. The streams are separated by poorly drained plains several miles in width, in which, by systematic ditching, the productiveness of the soil has been greatly increased.

AU SABLE CREEK AND NETTLE CREEK.

Au Sable Creek (spelled also Aux Sable) has a drainage area of about 218 square miles, and enters the Illinois 4.7 miles below the junction of the Des Plaines and Kankakee rivers. It drains much of the northern portion of the Morris Basin lying between the Minooka till ridge and the portion of the Marseilles moraine north of the Illinois River. It has widely branching headwaters which find their source in the Marseilles moraine. The lower course follows the outer or west border of the Minooka Ridge southward to the Illinois, and the east side of the watershed is very narrow. A portion of this basin is included in the Morris topographic sheet.

Nettle Creek, another stream draining the east slope of the Marseilles moraine, enters the Illinois from the north at Morris, about 5 miles below the mouth of Au Sable Creek. It also has widely branching headwaters leading southeastward from the Marseilles moraine. The drainage area is estimated by Cooley to be only 63 square miles.

MAZON CREEK, WAUPECAN CREEK, ETC.

Mazon Creek, with an estimated drainage area of 540 square miles, enters the Illinois at Morris, about 10 miles west from the head of the river. Like Au Sable Creek, it has a widely branching headwater drainage whose source is in the Marseilles moraine. The lower course leads northwestward, draining at right angles to that of the several tributaries. There is a sandy plain extending from the main creek eastward to the Kankakee, on which there is no perceptible dividing ridge. The headwater tributaries descend rapidly, but the main stream is rather sluggish. Wide intervals between the tributaries are imperfectly drained, but by systematic ditching the land has been rendered very productive.

Waupecan Creek and Hog Run are two small southern tributaries of the Illinois entering below the mouth of Mazon Creek and draining the portion of the east slope of the Marseilles moraine lying between the Illinois River and the Mazon watershed. Their combined area is only about

TOPOGRAPHIC MAP SHOWING DRAINAGE FEATURES NEAR OTTAWA, ILLINOIS.

Scale

1 0 1 2 3 4 MILES

Contour interval 10 feet

70 square miles. Like the headwaters of Mazon Creek, they flow northeastward down the slope from the moraine to the plain.

It will be observed that Mazon Creek and these streams drain the south part of the Morris Basin. A portion of this area appears on the Morris topographic sheet.

FOX RIVER.

For about 20 miles in the vicinity of the Marseilles moraine the Illinois receives no tributary worthy of mention, as may be seen by reference to the Marseilles topographic sheet. But just west of the Marseilles moraine, at a distance of 33 miles from the head of the Illinois, Fox River is received. Its drainage area is about 2,500 square miles, or more than one-third as great as the portion of the watershed of the present Illinois above the mouth of this tributary. It lies mainly in Illinois, but the source of the stream is in southern Wisconsin.

For a distance of nearly 75 miles from its source Fox River drains only a narrow strip among the morainic ridges of the composite belt previously described. In this portion of its course its fall amounts to but a few inches to the mile, and it expands at frequent intervals into lakes and marshes, between which are short spaces having a narrow and well-defined channel. Near the point of divergence of the Marseilles moraine from the Bloomington morainic system above Elgin, Illinois, the river begins a rapid descent to the low plain that lies on the outer border of the Marseilles moraine, and follows this plain to its mouth.

The stream has no valley until it begins the descent to this plain. It there for a few miles has cut to a depth of nearly 100 feet, but in the passage through the plain its bed is sunk to a depth of only 40 or 50 feet, except for a few miles near its mouth, where it cuts deeper to enter the Illinois. The valley is also narrow throughout its entire length, and presents a conspicuous contrast to the broad valley of the upper Illinois. Its channel even in the lower 75 miles has a breadth of only about one-eighth mile and a depth scarcely half as great as that of the neighboring portion of the Illinois, yet it is better favored than the Illinois for the development of a drainage line, there being no morainic ridge to cross and a proportionately small amount of rock to excavate. Instead of an excavation one-third as great as that of the upper Illinois, this stream has accomplished scarcely one-sixteenth as much work. These contrasts are well shown in the Ottawa

topographic sheet of this Survey, a portion of which is here reproduced (see Pl. XIX).

The principal tributaries of Fox River all lie on the west side, there being but a narrow strip of watershed on the east side of the river. Among the tributaries may be mentioned Nippersink Creek, which enters about 6 miles south of the State line; Blackberry Creek, which enters opposite Yorkville; Big and Little Rock creeks, which unite just before entering the river, 5 miles below Yorkville; Somonauk Creek, which enters opposite Sheridan, 12 miles farther down the river, and Big and Little Indian creeks, which unite near their mouths and enter the river about 10 miles above its junction with the Illinois. Nippersink Creek heads in the composite morainic belt in northern McHenry County and takes a zigzag course among its ridges through a series of marshes for a distance of nearly 20 miles before entering the river. Blackberry Creek, as previously indicated, occupies an esker trough in its middle course, whose size is many times greater than that of the remainder of the creek channel. Before entering the esker trough the creek winds about among morainic knolls near the south end of the composite belt. In its lower course the creek does not pass directly into Fox River, but follows down the valley about 8 miles, draining a portion of the gravel plain which borders the river. The remaining tributaries above mentioned all head in the Bloomington morainic system or on the slope of its inner ridge, and take a somewhat direct southeastward course to Fox River Valley, following the slope of the plain. They have narrow valleys and have sunk their beds but a few feet below the level of the plain, except near their mouths, where they have cut down to a level corresponding to that of Fox River. Some portions of the plain west of Fox River are naturally very imperfectly drained, but by ditching and tile draining they have been brought to a high degree of fertility. The slope of the plain averages usually several feet to the mile; consequently drainage is easily developed.

COVEL CREEK.

This small southern tributary of the Illinois drains an area of about 100 square miles lying between the Marseilles moraine and Farm Ridge, the inner ridge of the Bloomington morainic system. It enters the Illinois

about 3 miles below the mouth of Fox River. The basin drained by this stream, as previously described, carries sand ridges, which were perhaps formed by a lake-like expansion of the river prior to the opening of the channel to the west.

VERMILION RIVER.

This southern tributary of the Illinois should not be confused with a stream of the same name which leads into Wabash River from eastern Illinois. To distinguish these streams, the names Wabash-Vermilion and Illinois-Vermilion have come into use. Both streams have their sources in the Bloomington morainic system at the reentrant angle in southeastern Livingston and western Ford counties. The course of the Illinois-Vermilion is northwestward, while that of the Wabash-Vermilion is southeastward, from the elevated district in which they have their common source.

The Illinois-Vermilion has a drainage area of 1,300 square miles, and drains the district immediately south and west of the Marseilles moraine in Ford, Livingston, and southern Lasalle counties. The main stream follows the west or outer border of the inner ridge of the Bloomington system from source to mouth, but an east fork leads through this moraine. The other eastern tributaries find their sources in these morainic belts. A southern tributary—Rooks Creek—heads near Lexington in Cropsey Ridge, another weak moraine of the Bloomington system. The western tributaries drain a plain which slopes gradually eastward nearly to the border of the moraine. The western side of the watershed is much more extensive than the eastern, yet no streams worthy of note lead across it to the Vermilion. Its drainage is through small streams which pass directly down the slope to the river in somewhat parallel courses.

The unfavorable conditions for drainage along the Vermilion have been discussed on preceding pages. The plain through which it passes, as there noted, has little descent in the lower 40 miles of the river, and was apparently occupied by a marsh, if not by a shallow lake, until a stream had been given time to open a channel from the Illinois back several miles into the plain. Sandy deposits on the south border of the plain are thought to be due to the existence of a lake in the portion to the north. The narrowness of the channel of the Vermilion River near its mouth is well shown on the Lasalle topographic sheet.

LITTLE VERMILION RIVER, ETC.

Little Vermilion River enters the Illinois directly opposite the mouth of the Vermilion River, and sustains a similar relation to the inner ridge of the Bloomington morainic system, that ridge being immediately east of each stream. Its watershed, however, comprises only 150 square miles. The size and slope of its valley and the slope of bordering uplands, as well as the relation to the morainic ridge east of it, are well displayed on the Lasalle topographic sheet. The same sheet also brings out clearly the features of a neighboring small tributary of the Illinois—Spring Creek—which enters the river at Spring Valley. The features of another small northern tributary—Negro Creek—are brought out on the Lasalle and Hennepin topographic sheets.

The same sheets also bring out the features of All Forks Creek, a small southern tributary of the Illinois, entering the river about 5 miles above Hennepin. All Forks Creek, it will be observed, occupies a shallow depression leading westward parallel with the Illinois River. This depression was perhaps utilized, if not produced, in the early stages of drainage development by a portion of the Illinois River. It will be observed that a similar shallow depression also leads westward on the north side of the Illinois, passing just north of the cities of Peru and Spring Valley, which may also have been formed by the river in the early stages of its development. A more careful investigation of this portion of the Illinois, where the postglacial stream enters the preglacial valley, is necessary to bring out fully the history of the development of the present lines of drainage.

BUREAU CREEK.

Bureau Creek, which enters the Illinois from the northwest at the great bend of the river, has a drainage area of about 480 square miles. This watershed, as previously shown, is included mainly between the two prominent members of the Bloomington morainic system which are developed in the district north from the bend of the Illinois. In addition to the main creek there are several nearly parallel tributary streams, all flowing southwestward across the northeastern and eastern portions of Bureau County. The main stream swings around to the south and east, gathering in the

several parallel tributaries in this curving portion of its course. Its deflection from a southwestward course is caused by the change in the course of the moraine which lies on its northern and western border. This moraine furnishes only small northern and western tributaries to the main stream.

The watershed, with the exception of the great moraine on the north and west borders, shows a perceptible southwestward descent, amounting generally to several feet to the mile. In the headwater portions the main creek and also its tributaries have formed only shallow ditches, but in the lower course they have trenched deeply into the drift deposits, as may be seen by reference to the Hennepin topographic sheet.

Between the mouth of Bureau Creek and the city of Peoria, a distance of about 50 miles, the Illinois River receives no important tributaries. The largest is East Crow Creek, which has a drainage area of 226 square miles. Sandy Creek, another eastern tributary, drains 147 square miles; and Senachwine Creek, a western tributary, drains 132 square miles. No others have an area exceeding 100 square miles. The smallness of the western tributaries is due to the close approach of the bulky Bloomington morainic system to the west bluff of the Illinois. In most cases these tributaries lead somewhat directly from the moraine down to the valley, but Senachwine Creek has been deflected by a drift ridge into a course parallel with the moraine, and thus drains a larger area than the neighboring tributaries. The eastern tributaries lead directly westward across a slightly undulatory plain, which apparently offered conditions rather unfavorable for stream development, there being very little descent. The streams, however, have overcome this impediment by trenching deeply near their mouths, and have thus opened a fair drainage in that region. The features are well shown in the Hennepin, Lacon, and Metamora sheets.

KICKAPOO CREEK.

Kickapoo Creek, which enters the Illinois from the west at the city of Peoria, has a drainage area of 310 square miles, mainly situated on the Illinoian drift outside the limits of the Shelbyville moraine. The headwater portion, however, drains a narrow strip between the Shelbyville and Bloomington morainic systems, passing through the Shelbyville moraine just below the village of Dunlap. The relation of this stream to the morainic ridges,

and also the general features of its several tributaries in the headwater portion, may be seen by reference to the Dunlap topographic sheet.[1]

FARM CREEK.

This small eastern tributary of the Illinois which enters directly opposite the city of Peoria has its source in the Bloomington morainic system. As previously noted, it carries a moraine-headed terrace which opens into the Illinois Valley at a level about 170 feet above the stream, thus showing that at the Bloomington substage of glaciation the valley was filled to this unusually high level in that vicinity. The stream has now opened a valley down to the level of the 50-foot terrace which borders the Illinois, that offers a convenient line for approach to Peoria from the east, which is utilized by several railway lines.

MACKINAW RIVER.

This important tributary of the Illinois has a drainage area of about 1,200 square miles, which may conveniently be divided into three sections: (1) The headwater portion, lying inside the main ridges of the Bloomington morainic system; (2) the middle portion, comprising the section crossing the Bloomington and Shelbyville morainic systems and the narrow plain separating them; (3) the lower portion, embracing the meanders of the river through the Illinois River bottoms.

The upper portion drains a somewhat elevated till plain in north-central McLean and eastern Woodford counties, lying between the inner large moraine and Cropsey Ridge, a minor moraine of the Bloomington system. The length of this portion of the river is about 40 miles, and in much of its course it flows near the south border of the minor moraine. Several tributaries heading in the large moraine lead northward to the river across a sloping plain. Another tributary—Panther Creek—which drains several townships in eastern Woodford County, leads southwestward to join the river at the point where it enters the middle course. The streams in this upper portion have generally very shallow channels, seldom more than 25

[1] I am informed that by mistake an uncorrected photograph copy of the Dunlap sheet was sent to the engraver, instead of a corrected copy. The error involves chiefly an omission of a 50-foot contour on the uplands west of the Illinois. This should be borne in mind in the examination of the Dunlap sheet.

or 30 feet in depth, and also very narrow flood plains. The main stream, however, begins to deepen its channel before entering the large moraine, and has a depth of 60 to 75 feet at the inner border of the moraine.

In the middle course Mackinaw River has cut a channel across both the large moraines of the Bloomington system and also the Shelbyville moraine, with an average depth of nearly 100 feet. The width of the valley increases from about one-fourth mile in the inner part of the Bloomington belt to about a half mile at the outer part and to nearly a mile in its passage across the Shelbyville moraine. As previously indicated, its fall is very rapid, being usually several feet to the mile. The river receives but few tributaries in this middle course, and these drain only small areas. The largest tributary is Walnut Creek, which enters from the north between the two main ridges of the Bloomington system, and which drains probably 100 square miles. Another north tributary—Deer Creek—drains a portion of the plain between the outer Bloomington moraine and the Shelbyville moraine. Little Mackinaw Creek, a southern tributary, drains a portion of this plain south of the river.

In its lower course the Mackinaw River winds about in a shallow channel across the Illinois Valley for a distance of about 20 miles and makes a descent of about 75 feet.

QUIVER CREEK.

This eastern tributary of the Illinois has its entire course within the limits of the valley of the Illinois River. It is the only stream of consequence found in an area comprising not less than 200 square miles of sandy bottom. It is immediately bordered by a belt of mucky alluvium, averaging perhaps 2 miles in width, whose surface stands 20 feet or more below the level of the bordering sandy bottom. This appears to have been the former course of Mackinaw River, and was perhaps occupied also by a portion of the Illinois River. By systematic ditching much of the bordering districts have been drained into this channel. There are other bayous in this sandy bottom which are connected with the Sangamon River through Crane Creek. These also were probably once occupied by the Mackinaw River, together with a portion of the Illinois.

COPPERAS CREEK.

This small western tributary of the Illinois drains an area of about 150 square miles in southwestern Peoria County. Several of the tributaries, as well as the creek itself, have their courses largely determined by preglacial drainage lines which are only partially filled by glacial deposits. There are other small western tributaries of the Illinois between Copperas Creek and the mouth of Spoon River, which also have their courses largely determined by preglacial drainage lines.

SPOON RIVER.

This large western tributary of the Illinois has an estimated drainage area of 1,870 square miles. It enters the river opposite the city of Havana. The sources of the stream are in southwestern Bureau County, a few miles west of the great bend of the Illinois, and the course of the stream for nearly 100 miles is west of south, nearly parallel with that of the Illinois River. It then turns abruptly southeastward, and in a distance of about 25 miles joins the Illinois.

In its headwater portion Spoon River receives the drainage of the western slope of a portion of the Bloomington and Shelbyville morainic systems. With this exception the entire watershed lies outside the limits of the Wisconsin drift, occupying a region covered by Illinoian drift, upon which there is a capping of loess.

The course of the main stream, and also of several tributaries, appears to have been determined largely by preglacial drainage lines which have been but partially filled by the glacial deposits. The filling, however, has been so great that the present streams conform only in a general way to the course of the preglacial lines, and thus at a few places they trench upon the projecting rock points in the bluffs of the preglacial valleys, and give the appearance of being in courses independent of preglacial lines.

The river receives several tributaries, both on the east and on the west, which have a length each of 15 to 20 miles or more. These tributaries are usually widely branching, and the entire watershed displays a perfection of drainage such as does not occur within the limits of the Wisconsin drift. There appears to be on the main stream, and also on many of the tributaries, a more rapid descent in the headwater portions than in the lower

courses, a feature indicating a greater maturity of drainage than is characteristic of the Wisconsin drift; for, as already indicated, several of the large tributaries of the Illinois within the limits of the Wisconsin drift have their most rapid descent in the lower portion, the headwater portion being sluggish and imperfectly drained. These contrasts in drainage are only in part due to the natural advantages possessed by Spoon River, and they furnish an impressive line of evidence of the difference in the age of the drift sheets.

SANGAMON RIVER.

The Sangamon River has a larger watershed than any other tributary of the Illinois. However, its drainage area, estimated at 5,670 square miles, includes extensive plains in central Illinois which are inadequately drained, but which may, by extensive ditching, be drained into it.

The length of the river is about 180 miles. Its source is in the Bloomington morainic system in eastern McLean County, at an altitude of about 850 feet above tide, or about 430 feet above its mouth (the mouth being 419 feet). In the first 10 miles it makes a descent of 120 feet, thus leaving about 300 feet of fall for the remaining 170 miles of its course. The fall is far from regular, there being sections, often several miles in length, in which it is slight, between which are sections with more rapid fall. Thus in its course through Sangamon County, a distance of 36 miles, it falls only 38 feet, while in crossing Menard County, immediately below, it falls 67 feet in a distance of 30 miles, and in crossing Macon County, just above Sangamon, it falls 50 feet in about 30 miles. In the lower 23 miles, where it crosses the Illinois bottoms, its fall is only 16 feet.

The main stream flows for about 90 miles within the limits of the Wisconsin drift, leaving that drift a few miles west of the city of Decatur. In this portion of its course it receives no tributaries of importance, its immediate watershed being only 15 or 20 miles in width. As previously indicated, it follows the west border of the Cerro Gordo moraine for fully 30 miles below the village of Mahomet, and that moraine constitutes the east border of its watershed. Its channel is but 20 to 30 feet in average depth in the first 60 miles of its course, but in the next 30 miles, in which it crosses the Shelbyville morainic system and the elevated inner slope of the moraine, it has trenched to a depth of 75 feet or more. Upon leaving the Shelbyville system it again enters a shallow valley, scarcely 50 feet in

depth, and this it maintains nearly to the mouth of the stream. The depth, however, is increased nearly to 100 feet in portions of the course between Springfield and Petersburg. The portion lying outside the Wisconsin drift sheet, although generally shallow, is much wider than the portion within the limits of that drift sheet, and bears evidence of having been partially opened prior to the Wisconsin stage of glaciation.

The amount of excavation accomplished prior to the Wisconsin stage is especially well shown on tributaries of the Sangamon River, both north and south of the main stream, which in some cases have been beheaded because of the Wisconsin deposits. Thus Lake Fork, a small stream leading northwestward from the border of the Wisconsin drift in western Macon County, has a valley about 20 feet in depth and fully one-half mile in width, which was apparently formed entirely before the Wisconsin stage of glaciation, for it now carries no stream adequate to erode a channel. The Sangamon River and several of its tributaries are found to have similar broad shallow valleys bordering narrower valleys of somewhat greater depth. By affording this means for comparing the amount and kind of erosion carried on before and since the Wisconsin invasion the Sangamon watershed becomes an important district for investigation.

Several tributaries of the Sangamon have their sources within the limits of the Wisconsin drift, among which may be mentioned North and South Salt creeks, Kickapoo Creek,[1] and three headwater branches of Sugar Creek. Kickapoo and Sugar creeks join Salt Creek a few miles above its mouth, and therefore fall within the limits of its watershed. South Salt Creek heads on the outer border of the Bloomington morainic system, in southeastern McLean County, and flows southwestward across a gently undulating plain to its junction with North Salt Creek, about 5 miles east of Clinton. North Salt Creek has its source between the two large ridges of the Bloomington morainic system, very near the source of the Sangamon River. It passes southward through the outer ridge and across the undulating plain south of it to its junction with the South Fork. Each of these streams has a length of 25 or 30 miles above their junction. The united stream passes westward through the Shelbyville moraine, entering the outer border plain at Kenney, 8 miles southwest of Clinton. The general

[1] This Kickapoo Creek should be distinguished from a stream of the same name entering the Illinois at Peoria.

course of the stream continues westward to its junction with the Sangamon River, 50 miles below. It receives Lake Fork Creek from the south about 5 miles above Lincoln; Kickapoo Creek from the north about 4 miles below Lincoln, and Sugar Creek, also from the north, about 12 miles farther down. Its valley is much broader below the mouth of Lake Fork than above, and it seems probable that a larger stream occupied Lake Fork Valley prior to the Wisconsin invasion than occupied Salt Creek Valley. Indeed, the latter appears to be almost wholly a post-Wisconsin stream as far down as its junction with Lake Fork.

Kickapoo Creek finds its source between the two ridges of the Bloomington system, a few miles east of the city of Bloomington. Like North Salt Creek, it passes southward through the outer morainic ridge and, as previously noted, becomes the avenue of discharge for a gravel train heading in that moraine. It passes through the Shelbyville moraine near the village of Waynesville and skirts its outer border for a few miles west, when it turns southwestward into Salt Creek, entering that stream about 10 miles from its point of departure from the Shelbyville moraine.

The several headwater branches of Sugar Creek find their sources in the depression between the two main ridges of the Bloomington system, and pass thence southwestward through the outer moraine, where they become the avenue of discharge for the trains of gravel connected with that moraine. The several branches converge upon approaching the Shelbyville moraine and unite in the midst of the moraine. Upon emerging from the Shelbyville moraine, Sugar Creek Valley is separated from Kickapoo by an interval of only 1½ miles, and this is largely occupied by a plain of gravel built up by the joint work of the two streams. Instead of uniting with Kickapoo Creek, however, Sugar Creek turns westward, and joins Salt Creek about 12 miles below the mouth of Kickapoo Creek.

Sangamon River receives one important tributary from the south, known as South Fork. It drains the greater part of Christian County, and enters the river in Sangamon County, immediately east of the city of Springfield. An eastern branch of South Fork, known as Flat Fork, has evidently been beheaded because of the Wisconsin drift, in a manner similar to that of Lake Fork. The stream has its present head in the outer border of the Shelbyville moraine, but finds a broad shallow valley, far out of proportion to its needs, down which it passes to the Sangamon River.

The average width of the valley is nearly one-half mile, but its depth is only about 20 feet.

The Sangamon River also receives the drainage from a plain on its southwest border south and west from Springfield. This plain shows a perceptible descent toward the river, and the present divide between the tributaries of the Sangamon and several streams which flow directly westward to the Illinois apparently follows nearly the line of a preglacial rock divide. With this exception the borders of the Sangamon watershed appear to be determined by accumulations of drift.

CROOKED CREEK.

This western tributary of the Illinois, which enters about 14 miles below the mouth of the Sangamon, drains an area of nearly 1,400 square miles. Its watershed lies immediately southwest of the Spoon River watershed. It extends on the northwest nearly to the bluff of the Mississippi, there being one tributary in northern Hancock County, from which the Mississippi bluff is distant less than 5 miles.

The main stream has a southeastward course from eastern Hancock County to its mouth, a distance of 60 miles. No important tributaries enter from the west, but several creeks lead into it from the east, which have lengths of 15 to 20 miles or more. These eastern tributaries present a remarkable parallelism, and take a nearly uniform direction about S. 65° W. As previously indicated, one of these tributaries, known as East Crooked Creek, occupies a valley which continues beyond this watershed in direct course to the Mississippi, and which is thought to have been formed by a subglacial stream. (See discussion of Big Meadow channel, p. 481.) Shallow channels may also have been opened by the same agency along other eastern tributaries, and have occasioned their remarkably direct and parallel courses.

For a few miles near its mouth the course of Crooked Creek has been determined by a preglacial drainage line, but elsewhere the drainage appears to be nearly independent of preglacial lines. A portion of the divide between its watershed and that of Spoon River follows a low till ridge. This ridge, however, is only a partial cause for the divide, since the general altitude and slopes on its borders are such as to have located the line of separation between the watersheds at about the present divide.

McKEE'S CREEK.

This western tributary of the Illinois enters about 18 miles below the mouth of Crooked Creek, and has an estimated drainage area of 472 square miles. Its general course is southeastward from eastern Adams County, across southern Brown and northeastern Pike counties. Within a mile of its mouth it is joined by South McKee's Creek, which drains the northeast part of Pike County.

The greater part of the divide between McKee's Creek watershed and the small streams leading directly west into the Mississippi follows a series of ridges which belong to the system formed at the margin of the Illinoian drift sheet. Not only have these ridges been influential in determining the position of this divide, but, as already indicated, they have governed to some extent the courses of the small streams directly tributary to the Mississippi. The divide between Crooked Creek and McKee's Creek is nearly free from drift ridges, and stands but little higher than the borders of McKee's Creek Valley. Its elevation is, however, perceptibly greater than that of the immediate borders of Crooked Creek. The thickness of the drift is generally sufficient throughout this watershed to fill the preglacial drainage lines and render it necessary to develop lines along new courses.

INDIAN, MAUVAISE TERRE, AND BIG SANDY CREEKS.

Indian Creek is one of several small eastern tributaries of the Illinois entering the portion of the valley south of the mouth of the Sangamon. It has a drainage area of about 290 square miles, situated mainly in northern Morgan County. Its lower 10 miles are occupied in crossing the Illinois River bottoms, where it has little drainage outside its immediate channel. Its watershed on the uplands has a breadth of about 9 miles and a length of fully 20 miles. The general course of drainage is directly westward, across a gently sloping plain, and is independent of preglacial drainage lines. The divide at the east, however, is probably a preglacial rock divide.

Mauvaise Terre Creek drains a narrow strip immediately south of the Indian Creek watershed and has a drainage area of 275 square miles. It includes a strip leading westward across central Morgan County and northern Scott County, whose average width is scarcely more than 8 miles, but whose length is about 30 miles. Like Indian Creek, its course seems to

have been determined by the slope of a drift plain and is apparently independent of preglacial lines.

Big Sandy Creek, the next succeeding eastern tributary of the Illinois, has a drainage area of about 190 square miles. Its watershed is broader than either of the two preceding, but is much shorter, its extreme length from east to west being scarcely more than 18 miles. It comprises a district lying somewhat below the general level of the neighboring watershed. This fact, together with the absence of rock outcrops in the portion of the Illinois bluffs immediately north of its mouth, renders it probable that a preglacial drainage line traversed the midst of its watershed, though in a course not precisely coincident with that of the present stream.

APPLE CREEK.

Apple Creek has a drainage area of about 500 square miles, which includes southeastern Morgan, northern Greene, and northwestern Macoupin counties. Its course is southwestward, and the watershed has a length of about 40 miles. The greatest breadth is about 15 miles. Its lower course appears to be along the line of a preglacial valley, but the headwater portion and also the majority of the tributaries show little dependence upon preglacial lines. The drift is comparatively thin over much of the watershed, and streams have cut down into the underlying rocks at many points.

MACOUPIN CREEK.

Macoupin Creek is the most important eastern tributary south of the Sangamon River, its drainage area being nearly 1,000 square miles. It drains the greater part of Macoupin County and a portion of the neighboring counties on the east and west. Its watershed is widely branching in the middle portion and tapers toward either end, giving a broadly ovate outline. With the exception of the headwater portion above Carlinville, the main stream apparently has its course determined by a preglacial line, there being a broad depression, deeply filled with drift, through which the creek takes its course. The tributary streams appear to be largely independent of preglacial lines. The extent of the watershed on the north and south appears to be determined in large part by preglacial divides, but the influence of preglacial divides is less apparent at the eastern border of the watershed.

OTTER CREEK.

This small eastern tributary of the Illinois drains an area of about 100 square miles embraced between the mouth of Macoupin Creek and the elevated rock ridge which forms the bluff of the Mississippi and Illinois in southern Jersey County. It apparently follows in a general way a preglacial drainage line having about the same watershed.

KASKASKIA RIVER DRAINAGE BASIN.

KASKASKIA RIVER.

The Kaskaskia or Okaw is the principal river traversing southern Illinois. With a length of 180 miles, it drains nearly 6,000 square miles. Its source is in the Champaign morainic system immediately west of the city of Champaign, at an altitude of about 730 feet above tide; it enters the Mississippi near Chester, in Randolph County, at an altitude of 342 feet. Its descent is generally gradual, the most rapid section of its course being in its passage through Moultrie County, where it makes a descent of 55 feet in about 18 miles, or 3 feet to the mile. In the headwater portion there is a fall of only 110 feet in the first 50 miles. In places there are pools several miles in length, the most conspicuous of these being found in St. Clair County, where, in a distance of 20 miles, the fall is scarcely 10 feet.

The stream is subject to great variations in volume, for it drains a region in which the substrata are of compact clay, which promotes a rapid run off, and furnishes but little water in seasons of drought. A rise of 20 feet in its lower course is not rare, and its flood plain has been built nearly to that height above the stream bed.

The upper 80 miles of this stream lies within the limits of the Wisconsin drift. The stream emerges from the Shelbyville moraine at the city of Shelbyville. In this headwater portion there are no noteworthy tributaries, and the watershed has a breadth of only 10 to 20 miles. The channel is narrow and shallow from the source down nearly to the inner border of the Shelbyville morainic system. There it becomes deeper, with a narrow trench having an average depth of nearly 75 feet. Near its point of emergence from the Shelbyville system two railway bridges extend from bluff to bluff, thus avoiding the necessity for a descent into the valley, and yet the bridges are only about one-fourth mile in length.

Upon entering the older drift the valley continues small for a few miles, but is perceptibly increased in size below the point of entrance of Robinson Creek. This stream appears to follow the lower course of a drainage line whose former headwater portion has been concealed by the Shelbyville drift sheet. Its valley has a breadth of nearly a half mile, and this breadth characterizes the portion of the Kaskaskia immediately below its mouth. Upon entering Fayette County the river soon opens into a broad preglacial valley whose course farther north has been concealed. The valley has a width of about 3 miles near Vandalia, but increases to greater width farther south. Masked as it is by the drift, it presents the appearance of a broad shallow basin rather than a river valley. This basin-like valley continues nearly to the mouth of the stream, where the width contracts abruptly to about a mile upon entering the Eocarboniferous limestone which there borders the Mississippi Valley.

This stream receives but one noteworthy eastern tributary—Crooked Creek—and two western tributaries—Shoal Creek and Silver Creek. Crooked Creek[1] is relatively unimportant, as it drains only a narrow strip, 35 or 40 miles in length, leading from north-central Marion County southwestward past Salem and Centralia and entering the Kaskaskia a few miles below Carlyle. Coal shafts at Salem, Odin, and Sandoval show the presence of a preglacial valley on the north border of this watershed, with bed 100 feet or more below the present surface, but the present stream flows through a region of comparatively thin drift.

SHOAL CREEK.

Shoal Creek has a drainage area of about 1,000 square miles, or one-sixth the entire watershed of the Kaskaskia River. Its watershed embraces the greater part of Montgomery and Bond counties and the western part of Clinton County. The stream enters the Kaskaskia in the southwest part of Clinton County, about 20 miles below Carlyle. In the headwater portions there are three streams, known as West, Middle, and East Shoal creeks. West and Middle Shoal creeks are each about 20 to 25 miles in length and unite near Walshville in southwestern Montgomery County. The united stream below that point is known as West Fork to its junction with East Shoal Creek, 20 miles farther south. East Shoal Creek has a length of

[1] This stream should not be confused with one of the same name that enters the Illinois River.

about 40 miles, but drains a much narrower strip than that of West Fork. Below the junction of the East and West forks the stream has a length by direct course of about 25 miles.

This watershed has a perceptible southward descent, the altitude at the headwaters being 700 to 750 feet at tide and at the mouth only 400 feet. The mouth of the creek is but 380 feet. The three streams have each formed channels 50 to 75 feet or more in depth and nearly one-fourth mile in average width in their passage through southern Montgomery County. A similar depth is maintained as far down as the junction of the East and West forks near Greenville. Below this point the valley is more shallow and the stream soon enters the Kaskaskia Basin, where its valley is but little lower than the basin plain.

East Shoal Creek is bordered closely on the east throughout its entire length by a system of drift knolls and ridges which, as previously described, attain great prominence in eastern Montgomery County. Shoal Creek passes through a break in this system of ridges just below the junction of the East and West forks, beyond which its course is largely independent of drift ridges. Middle Shoal Creek winds about among prominent drift knolls near Hillsboro, and West Shoal Creek is deflected eastward by a ridge of drift at its junction with Middle Shoal Creek. With these exceptions the streams are not markedly deflected by drift aggregations. They pursue, as a rule, nearly direct southward courses, following the slope of their watershed.

Their courses appear to be mainly independent of preglacial drainage lines. East Shoal Creek touches the line of a deep preglacial valley near Greenville, but above that point it has opened a new course, in places trenching into the rock. Even the lower course seems to be largely independent of any preglacial line of drainage.

SILVER CREEK.

Silver Creek has its source in southeastern Macoupin County and flows nearly due south its entire length of fully 50 miles, crossing the eastern part of Madison and St. Clair counties. Its watershed is scarcely 10 miles in average width, and has an area of about 500 square miles. At the source of the stream the altitude is fully 650 feet, but the watershed descends within 10 miles to about 550 feet, and in the next 15 miles to

about 500 feet above tide, while the stream falls to about 450 feet. In the lower half the watershed is diversified by drift ridges and knolls which rise abruptly in some cases to a height of 75 feet or more above border districts. These ridges for a few miles in southeastern Madison County constitute the east border of the watershed, but just south of the line of Madison and St. Clair counties the stream passes through the main belt of ridges, and has but few prominent ridges and knolls on its east side below that point. At its mouth the stream has an elevation of only 370 feet, and the border districts, aside from knolls, stand scarcely 400 feet above tide.

This stream, like Shoal Creek, appears to be largely independent of preglacial drainage lines. It trenches into the rock at numerous points along its course, and its immediate bluffs stand at the general level of bordering uplands. There may, however, have been a preglacial divide near the headwaters of the creek.

BIG MUDDY RIVER DRAINAGE BASIN.

The only remaining important tributary of the Mississippi is the Big Muddy, a stream draining about 2,400 square miles in the low district lying north of the "Ozark Ridge." It is the line of discharge for the greater part of Williamson, Franklin, Jefferson, Perry, and Jackson counties and the southeastern part of Washington and the southern part of Marion County. The lower 20 miles of its course lies within the Mississippi bottom.

With the exception of the elevated district on the south border, which stands 600 to 800 feet above tide, this watershed has few points rising above 550 feet. It stands mainly between 400 and 500 feet above tide. The immediate borders of the main valley fall below 400 feet, and the mouth of the stream at low water in the Mississippi is but 320 feet.

The principal tributaries of Big Muddy River are Beaucoup Creek and Little Muddy River, which drain the western side of its watershed. An eastern tributary—Crab Orchard Creek—drains about 250 square miles of the district bordering the "Ozark Ridge."

Throughout the greater portion of its course Big Muddy River occupies a preglacial line of drainage, and meanders about in the broad bottoms which have been filled with drift and alluvium to an elevation of 50 to 100 feet or more above the rock bottom. Just below Murphysboro, however,

the valley becomes constricted to a width of about a mile in its passage through the elevated ridge which there borders the Mississippi Valley. Little Muddy River and Beaucoup Creek, with their principal tributaries also flow through broad preglacial channels which carry heavy deposits of drift and alluvium.

Possibly the watershed of Crab Orchard Creek has received important modifications as a result of glaciation. The headwater portion of the South Fork of Saline River, a tributary of the Ohio, leads down directly toward Crab Orchard Creek from the elevated portion of the "Ozark Ridge" to a low plain filled to a considerable depth with glacial deposits. It there turns abruptly eastward, following nearly the glacial boundary. It probably continued northwestward into Crab Orchard Creek in preglacial times. A considerable area in northwestern Williamson County also has been filled to such a depth with glacial drift that the preglacial lines are completely concealed. Throughout the greater part of the Big Muddy watershed the drift is very thin, and rock divides separating the preglacial drainage areas are plainly discernible.

SALINE RIVER DRAINAGE BASIN.

This small watershed tributary to the Ohio drains the portion of southeastern Illinois immediately north of the "Ozark Ridge." The South Fork follows closely the base of the ridge, receiving small tributaries which descend the slope of the ridge. The lower course of the main stream is also along the base of the ridge. The Middle Fork rises in southeastern Franklin County and takes a southeastward course past Harrisburg into the South Fork, draining much of Saline County. The North Fork has its source in western Hamilton County and leads southeastward, draining the south half of Hamilton, the northeast part of Saline, the southwest part of White, and the west part of Gallatin County, joining the South Fork at the town of Equality, about 12 miles west of Shawneetown.

These three forks of the Saline River, and also their principal tributaries, are, in the main, reestablished along preglacial lines and take meandering courses through broad valleys which have been filled to an elevation of 50 to 100 feet or more above their rock bottoms. As above noted, a small part of the watershed of South Fork has probably been added to this drainage system as a result of glaciation, but with this exception no

deflections worthy of note have been observed. The South Fork follows nearly the glacial boundary throughout much of its length, but apparently occupies a preglacial channel.

CACHE RIVER.

A change of some consequence has occurred in the Tertiary lowland in southern Illinois. The Ohio at one time discharged either wholly or in part through the "Cache Valley," which crosses southern Illinois a few miles north of the present course of the Ohio. Its point of connection with the Cache Valley was immediately north of Metropolis, Illinois, where for a distance of 4 or 5 miles a clay deposit has accumulated in the line of the old valley. The surface of this clay deposit stands only about 75 feet above the present stream and is much lower than the surface of the Tertiary deposits on either side. Wells indicate that the clay has sufficient depth to extend to river level, and it may extend much lower. The surface of this clay deposit presents much less erosion than that of the bordering Tertiary lowland and evidently is of far more recent date. Judging from the amount of erosion displayed it is no older than the Illinoian drift sheet. It may possibly be as recent as the white clay of southern Illinois, which seems referable to the Iowan stage of glaciation. It is not known as yet whether this channel formerly constituted the sole line of discharge for the Ohio. Possibly the river divided its waters between the Cache channel and its present channel. The cause for the filling which led to the abandonment of this valley by the Ohio is not clearly understood.

The Ohio River falls within the limits of a district covered by another report, hence it is not taken up here.

WABASH RIVER DRAINAGE BASIN.

The large drainage basin of the Wabash River, with an area of about 33,000 square miles, extends from western Ohio westward across the central portion of Indiana and thence southward to the Ohio, embracing on the west side of its watershed a considerable portion of southeastern Illinois. About one-half of this drainage area was covered by the Illinois glacial lobe, and many important changes have resulted from its occupancy of the region. Indeed, there appears to be very little similarity of outline between the present watershed and the watershed which in preglacial times had its

discharge through the lower course of the Wabash. The westward-flowing portion of the Wabash, with its several tributaries, traverses a district lying mainly outside the limits of the Illinois lobe and appears to be entirely independent of preglacial drainage lines, for the drift deposits have been built up to a level above the preglacial rock divides. The headwater portions of White and East White rivers, which are the principal tributaries of the Wabash, seem also to be very largely independent of preglacial lines. There remain only the lower courses of the Wabash, and of tributaries entering below the great bend near Covington, Indiana, which are governed to any considerable extent by the preglacial lines of drainage. These all fall within the limits of the Illinois lobe or of unglaciated districts immediately outside.

Only the tributaries of the Wabash which enter within the limits of the Illinois glacial lobe are discussed in this place. The remainder of the watershed falls within the limits of a district covered by another report, now in preparation.

THE PREGLACIAL WABASH VALLEY.

The Wabash River enters a preglacial valley just above the city of Lafayette, which probably furnished a line of discharge for a considerable territory on the north and west. The river, however, remains in this preglacial valley for only a few miles; it soons turns southwestward across a rock point, while the preglacial valley apparently takes a longer route to the west and south, coming to the river at its great bend near Covington. From Covington southward the stream follows nearly the line of a preglacial valley to its mouth, though in a few places it cuts off rock points which projected into the preglacial valley.

Above Terre Haute this preglacial valley has been opened only a part of its width by the present stream, yet it shows a breadth of 2 to 4 miles. Below Terre Haute the bottoms of the present stream extend from bluff to bluff of the preglacial valley. The breadth increases from about 5 miles at Terre Haute to fully 15 miles near the junction of the Wabash with the Ohio.

Few data have been obtained concerning the elevation of the rock bottom, but these uniformly indicate a level considerably below that of the present stream. So far as collected, they do not show a descent in passing

from north to south, but they are scarcely sufficient to prove a warping of the valley floor. A boring in the abandoned channel west of Lafayette enters rock at the remarkably low altitude of about 300 feet above tide, while at Terre Haute several borings made in the middle part of the valley enter rock at 345 to 360 feet above tide. Between these two points borings at Clinton and Montezuma enter rock at an elevation slightly higher than at Terre Haute. The elevation of the rock floor at Shawneetown, Illinois, just below the mouth of the Wabash, is shown by an oil boring to be but 240 feet above tide. As this boring was made near the border of the valley, the rock floor may there reach a still lower elevation.

MINOR DEFLECTIONS OF THE WABASH.

At several points the Wabash makes slight deflections from its broad valley to cross projecting points of the preglacial bluff, the most notable instances being just above the city of Vincennes, Indiana, and a few miles below New Harmony. In each place the broad valley of the Wabash passes around the western side of the projecting point, while the stream cuts across in a somewhat narrow valley. It is not entirely certain that these deflections are due to glaciation. Possibly they have been caused by encroachments of the stream upon the rock divides in a manner suggested in explanation of the deflections of the Mississippi south of the limits of glaciation. The question of the cause of the deflection must for the present remain open.

LITTLE WABASH RIVER.

This western tributary of the Wabash, which drains about 3,000 square miles of southeastern Illinois, enters the river only 8 miles by direct line from its junction with the Ohio. Its source is in the Shelbyville moraine in southwestern Coles County, and its course is slightly west of south for 50 miles, to northern Clay County, beyond which point it is east of south through Clay, eastern Wayne, and eastern White counties, a distance by direct line of about 75 miles. Its most important tributary is Skillet Fork, which enters from the west near Carmi. The length of this tributary is about 65 miles, not including the windings of the stream, and it has a watershed of nearly 1,000 square miles.

The watershed of the Little Wabash, including this large tributary,

has an ovate form, its middle portion being much broader than the upper and lower portions. It extends on the west to the watershed of the Kaskaskia, on the south to that of Saline River, and on the east to the Embarras and Bon Pas watersheds. The elevation of the headwaters of the main stream is about 700 feet, but the watershed falls to about 600 feet in the 30 miles to Effingham, to about 500 feet in the next 30 miles to Louisville, and to about 450 feet in the lower half. The elevation of the mouth of the stream is 323 feet above tide. The headwaters of Skillet Fork are only about 550 feet, thus giving a fall of but 100 feet in the watershed in passing across the broad middle portion from northwest to southeast.

The main stream is largely independent of preglacial lines in its upper 40 or 50 miles, but the remainder of its course is determined by a broad preglacial valley, except for a short distance just below Carmi, where it cuts across a projecting spur of hills leading in from the west. This valley, like other valleys in that region, has been filled in its lower course with drift and alluvium to a level perhaps 100 feet above its rock bottom. It thus covers low projecting points of the bluffs, and these are in some cases touched by the present stream, but the spur of hills near Carmi rises much above the level of the valley filling. The cause of the deflection of the stream across it, like that of similar deflections on the Wabash, has not been satisfactorily determined. The small tributaries of Little Wabash usually enter this valley through preglacial lines, but their headwaters are somewhat independent of the preglacial drainage. Skillet Fork and its chief tributaries occupy preglacial valleys throughout much of their length.

BON PAS RIVER.

This small western tributary of the Wabash, with a drainage area of about 250 square miles, is the line of discharge for a district in Richland, Edwards, and Wabash counties, lying between the watersheds of Little Wabash and Embarras rivers. Its course is mainly along a preglacial line which has been filled in its lower course to an elevation of 60 feet or more above the rock bottom. The watershed outside of the preglacial line of drainage and its tributaries has only a very thin deposit of drift; hence scarcely any change of drainage has resulted from the glaciation.

PATOKA RIVER.

This eastern tributary of the Wabash has a drainage area of nearly 1,000 square miles. Its watershed is long and narrow, being about 80 miles in length and less than 15 miles in average width, and lies between the watershed of East White River and the watersheds of several small streams which are directly tributary to the Ohio. The interesting drainage modifications which resulted in the production of the present Patoka River have already been considered (pp. 98–102).

WHITE RIVER.

The entire watershed of White River is about 11,000 square miles. Exclusive of East Fork it embraces about 6,000 square miles. The East Fork enters the district covered by the Illinois lobe only in the portion below the bend west of Shoals, and therefore lies mainly outside the field of the present discussion, which is restricted to the lower course of the main White River.

Near Martinsville, in southern Morgan County, White River leaves the district which has been covered by more eastern portions of the ice sheet, and from this point to its mouth, a distance of 125 miles by direct line, lies within the limits of the district covered by the Illinois lobe. That lobe encroached only a few miles upon territory east of White River, the greatest known extension being about 20 miles, at points where it touches upon East White Valley east and south of Loogootee in western Martin County. Throughout much of the distance below Martinsville the glacial boundary is within 10 miles east of the east bluff of the present river.

The valley of White River for a few miles below Martinsville, although including sections of a preglacial line or lines, has not been definitely connected with the preglacial line occupied by the stream in its lower course. The river crosses a rock ridge just below Ramona, another just above Spencer, while below Spencer it flows for a few miles in a narrow shallow channel among hills and ridges, there being apparently no definite preglacial drainage line to control its course. It occupies a preglacial valley from the mouth of Raccoon Creek down to Worthington, having a width of nearly a mile. Near Worthington the valley joins a larger preglacial valley, 2 to 2½ miles wide, which leads in from the north along the lower

course of Eel River. From this point to its mouth the course of the stream is nearly coincident with a broad preglacial line.

At Worthington there is a minor stream deflection. The preglacial valley of Eel River leads southward, while the present stream passes eastward into White River through a gap in a line of hills that continues south a few miles in the midst of the broad valley of White River. It is probable that this line of hills is the remnant of a narrow ridge separating the preglacial Eel River Valley from the smaller preglacial valley coming in from the northeast.

Below the junction of these two valleys White River has a valley of irregular width, ranging from 3 miles to fully twice that width. Broad low tracts extend up tributaries several miles. They are conspicuous on the west side, in both Greene and Knox counties, but on the east side they first become conspicuous in Daviess County south of Greene. These lowlands are deeply filled with drift and appear to be the lines occupied by preglacial tributaries. They are now mainly occupied by very small creeks.

Attention has already been called to some interesting deflections of eastern tributaries of White River in Owen and Greene counties, Indiana, evidently caused by the presence of the ice sheet, deflections which were discovered by Mr. C. E. Siebenthal, of the Indiana survey. Other deflections, also discovered by Siebenthal, appear to be referable in great part to drift filling, occurring as they do within the limits of glaciation. Thus Raccoon Creek makes a slight detour into its old south bluff 1½ to 2 miles below Freeman, its former course being indicated by a slight sag or depression lying north of the present stream. A similar though somewhat greater departure is made by Richland Creek near Tulip, about 6 miles above its mouth. A deflection of a different class was noted by Siebenthal in the basin of McCormack's Creek east of Spencer. This basin apparently had subterranean drainage prior to the ice invasion, but was compelled to make a surface channel after the drift deposition.[1] The creek has falls which have cut back a gorge in limestone about 1 mile from White River. The gorge is smaller and the stage of development less advanced than in gorges on similar-sized streams of northwestern Illinois. But as the rock is somewhat harder than that bordering the gorges of northwestern Illinois, no great difference in age need be inferred.

[1] See Twenty-first Ann. Rept. Indiana Geol. Survey, 1896, pp. 301, 302.

The drift has sufficient thickness on the west side of White River to render the tracing of preglacial drainage lines difficult if not impracticable. A smooth drift plain extends west from the bend of Eel River in southwestern Clay County to the Wabash Valley in Vigo and Sullivan counties, in which preglacial lines are almost entirely concealed. The preglacial divide was probably far from coincident with the present divide. In more elevated districts east of the bend the drift is in places filled to the level of the high rock ridges, completely disguising some of the lines of connection. For example, just north of the town of Spencer a preglacial valley connects with White River, which, within a mile to the north, becomes traceable only by means of well records, there being no depression between rock ridges to indicate its course. This is thought to lead through to Mill Creek, connecting with its valley just above the falls at Cataract. But whether formed by a stream flowing northward or in the reverse direction is not known.

EMBARRAS RIVER.

This western tributary of Wabash River drains an area of about 2,000 square miles in eastern Illinois. Its source is in the Champaign morainic system, immediately south of the city of Champaign. For about 20 miles it flows between the outer and main ridge of the Champaign system, but passes through the outer ridge in northern Douglas County. It then bears southeast for about 10 miles to a small till ridge, correlated with the Cerro Gordo moraine, which it crosses in southeastern Douglas County. The course is then slightly west of south for 25 miles, at which point it leaves the Shelbyville or earliest Wisconsin sheet of drift. It continues southward 25 or 30 miles farther to the vicinity of Newton, where it changes to a southeastward course and maintains this course to its mouth, a distance of 50 miles.

The portion lying within the limits of the Wisconsin drift drains a narrow strip and has a very small channel. Upon emerging from that drift it at once enters a much broader valley, which appears to have been excavated nearly to its present dimensions prior to the Wisconsin stage of glaciation, for the valley gravels connected with the Shelbyville moraine lead down the river bottom in such manner as to indicate the existence of the valley at the time of their deposition. Upon following the valley down, its width increases from less than a mile at the border of the Shelbyville

moraine to about 2 miles at Newton, and to 3 or 4 miles in the lower course of the stream. The portion below Newton has its course determined largely by a preglacial line of drainage, and possibly the preglacial line extends up the valley as far as the vicinity of Greenup, 18 miles above Newton. This upper portion, however, may prove to have been entirely excavated in an interglacial stage.

The Embarras River has but one large tributary—Hickory Creek—which heads in the Shelbyville moraine in southern Edgar County and leads southward across western Clark and eastern Jasper counties, a distance of over 40 miles, entering the Embarras about 10 miles below Newton. The course of this stream is probably nearly coincident with the preglacial line in its lower 20 miles, and possibly the upper portion is determined by a preglacial line. At least the drift is somewhat thicker along the borders of the stream than on neighboring districts to the east and west, while the altitude is somewhat lower.

BUSSERON CREEK.

This small eastern tributary of the Wabash has its source on the clay plain at the borders of Clay and Vigo counties, near the bend of Eel River, referred to above. Its course is southwestward across Sullivan County into the Wabash Valley. For a few miles near its mouth the stream evidently occupies a preglacial line of drainage, but its headwater portion is apparently independent of preglacial drainage.

BIG RACCOON CREEK.

This stream with its main tributary, Little Raccoon Creek, drains an area of about 500 square miles in western Indiana, mainly in Parke County, but including portions of Boone, Hendricks, Montgomery, and Putnam counties. Its source is in southwestern Boone County, and it takes a southwestward course from this point to southern Parke County, a distance of fully 50 miles by direct line, being mainly independent of preglacial lines. It there enters a channel which formerly carried a part of the drainage into Wabash River, and follows this channel northward about 15 miles before entering the Wabash. Little Raccoon Creek joins Big Raccoon at the point where this old channel of the Wabash is entered, and apparently follows a preglacial valley in its lower course. The northward deflection of the Big Raccoon has probably resulted from a silting up of

the south end of the old Wabash Bayou by the sediments brought down by the creek, for it seems probable that the creek continued southwestward into the Wabash along the south end of the channel opened by that stream for some time after the abandonment of the channel by the river. The abrupt change in the rate of fall would naturally produce an accumulation of silt at the point where it entered the old bayou of the Wabash, and this may have resulted in the deflection of the stream northward through an unfilled portion of the bayou. The watershed of Big Raccoon and Little Raccoon creeks lies mainly within the Wisconsin drift, but in southern Parke County it lies outside that drift.

SUGAR CREEK.

Sugar Creek, another eastern tributary of the Wabash, enters the river about 8 miles above the mouth of Big Raccoon Creek. It drains an area of perhaps 900 square miles, embracing southern Clinton, northern Boone, central Montgomery, southeastern Fountain, and northern Parke counties. Its length is about 80 miles by direct course, but the width of the watershed scarcely reaches 25 miles at any point, and the average width is not more than 12 miles.

This stream lies wholly within the limits of the Wisconsin drift, and, with the possible exception of a few miles near its mouth, has a course independent of preglacial lines. Its rock gorges, which set in a few miles below Crawfordsville, afford some of the most picturesque scenery in the State. Above Crawfordsville the stream has a shallow channel which touches the rock at only a few points. At the headwaters the drift is shown by deep wells to have a thickness of 250 to 300 feet. At Crawfordsville a preglacial valley is crossed whose rock floor is more than 100 feet below the present stream.

This stream cuts through a moraine of the Champaign system in southwestern Montgomery County, below which point it crosses a plain lying north of the moraine. The headwater portion above Crawfordsville lies within the limits of the Erie Glacial Lobe.

VERMILION RIVER.

This western tributary of the Wabash drains about 1,500 square miles in eastern Illinois. Its lower course for a distance of about 10 miles lies within the State of Indiana, but it there drains only the immediate borders

of the valley. The headwaters are in the midst of the Bloomington morainic system at the reentrant angle in Ford and Livingston counties, Illinois, and only a few miles from the headwaters of a stream of the same name flowing to the Illinois. To distinguish it from that stream the name Wabash-Vermilion has come into use.

The middle or main fork has a southward course for a few miles from its source, between two ridges of the Bloomington system in Ford County, locally known as the Roberts and Melvin ridges. It then passes through Melvin Ridge and receives a tributary draining a sag or narrow plain lying between that ridge and the outer moraine of the Bloomington system. It takes a southeastward course through this narrow plain across southeastern Ford, northeastern Champaign, and western Vermilion counties, to the village of Potomac. There it turns abruptly southward and passes through the outer ridge of the Bloomington system. Upon emerging from this moraine it receives West or Salt Fork, which drains a plain in eastern Champaign and western Vermilion counties lying between the Bloomington and Champaign morainic systems. The united stream flows east about 6 miles to the city of Danville, where North Fork leads in from the north. That fork drains only a small area among the ridges of the Bloomington system in eastern Vermilion County, Illinois, and adjacent parts of Indiana. From the city of Danville the stream leads southeastward through a till plain to the Wabash Valley. In this portion it trenches considerably into the rock, but above the immediate vicinity of Danville, so far as known to the writer, no rock is encountered by any of the streams.

The entire drainage system is independent of preglacial lines, for the drift has built up the surface above the level of the rock divides. A boring at Danville Junction, Illinois, and one near Eugene, Indiana, each strike into a preglacial valley in which rock is first encountered at a level 100 feet or more lower than rock ledges in that vicinity which have been cut into by the present stream in deepening its valley. There is no surface indication of the course of the preglacial drainage, but it may be inferred that it passed from the points named into the preglacial valley occupied by the Wabash. The Vermillion also crosses a preglacial valley a few miles below Danville. Its bottom there spreads out to a width of more than a mile, or to more than twice its usual width. This feature is well shown on the Danville topographic sheet.

LAKE MICHIGAN DRAINAGE BASIN.

Lake Michigan receives the drainage of only a very narrow belt in northeastern Illinois and northwestern Indiana, comprised mainly in the drainage areas of Chicago and Calumet rivers. It drains about one-half the area of the southern peninsula of Michigan and 1,500 square miles of the northeast part of Indiana. It drains also an area of several thousand square miles in the northern peninsula of Michigan and adjacent portions of Wisconsin, mainly tributary to Green Bay. South of the Green Bay drainage system only a narrow belt is tributary to the lake. The watershed draining to Lake Michigan is estimated to be 45,000 square miles, and the total area of the basin 68,100 square miles, the lake area being 22,400 square miles.[1]

In the present discussion only that portion of the watershed is considered which borders the southern end of the Lake Michigan Basin and lies within the limits of the Illinois glacial lobe.

CHICAGO RIVER.

With the exception of a few miles at the headwaters of the North Fork, this small drainage system lies within the limits of Lake Chicago. The South Fork, as previously noted, apparently has afforded a line of discharge for the Des Plaines River from the time of the withdrawal of the lake down nearly to historic times, the size and depth of its channel being such as would seem to demand the work of a stream as large as the Des Plaines. The southward course of the North Fork, outside the limits of the lake bottom, is occasioned by till ridges of the Lake Border morainic system, the one on the east preventing direct discharge into Lake Michigan. Within the limits of Lake Chicago the stream follows the slope of the old lake bottom.

CALUMET RIVER.

The headwaters of the Calumet River are in the Valparaiso morainic system south of Michigan City, Indiana. Its several southern tributaries are also found in the inner slope of the Valparaiso morainic system. These tributaries lead down the slope to the plain covered by Lake Chicago. Their courses are there controlled to some extent by the line of sand dunes

[1] Rept. U. S. Deep Waterways Commission, 1896, p. 149.

formed along the beaches of the old lake, and to a slight extent by till ridges, as in the case of the portion of Calumet River in Porter County, Indiana. This stream now has its mouth at South Chicago, in Illinois, but a former channel carried its discharge eastward to the head of Lake Michigan in northeastern Lake County, Indiana. There is a tradition that the change to the present course was brought about by dragging canoes across the low portage between Calumet River and Calumet Lake.

TRAIL CREEK.

This small tributary of Lake Michigan entering at Michigan City, Indiana, owes its peculiar T-shaped drainage to the presence of a till ridge. The arms of the T are formed by streams flowing on the outer or south border of the ridge, which upon meeting pass through it and take a more direct course toward Lake Michigan.

GALIEN RIVER.

The Galien River drainage system consists of two rivers, North Galien and South Galien, which unite about 5 miles from the point where the stream enters Lake Michigan, at New Buffalo, Michigan. The South Fork has two branches, one of which, like the branches of Trail Creek, has a course nearly parallel with the shore of Lake Michigan, caused by the same till ridge which governs the course of the headwater portion of Trail Creek. The other branch of the South Fork heads in the Valparaiso morainic system and takes a general northwestward course toward the lake.

The North Galien River has several headwater tributaries leading down from the Valparaiso morainic system and uniting just outside the outer till ridge of the Lake Border system. Upon passing through this ridge the stream turns southwestward along a sag or narrow plain lying between Outer and Covert ridges. Upon joining the South Galien River the united stream passes through Covert Ridge and soon enters Lake Michigan.

ST. JOSEPH RIVER.

This large eastern tributary of Lake Michigan has a drainage area of about 4,000 square miles, exclusive of Pawpaw River, which joins it within a mile of its mouth. Of this drainage area 3,550 square miles lie above South Bend, Indiana, the point where the St. Joseph formerly connected

with the Kankakee. It is only the portion below South Bend which falls within the limits of the present discussion.

Between South Bend and Niles the St. Joseph River has its course through a gravel plain that lies outside the Valparaiso morainic system. This gravel plain is connected on the south with the Kankakee gravel-and-sand area. The gravel plain also continues northeastward from Niles up the Dowagiac Valley nearly to the source of that stream. Just below Niles the St. Joseph River turns westward around the north end of a sharp moraine which apparently pertains to the Saginaw lobe (see Pl. XV), but at the village of Buchanan it leaves that moraine and enters the Valparaiso morainic system. It emerges from the Valparaiso system about 15 miles below Buchanan. Its course is then northwestward into Lake Michigan, with only slight deflections in passing the two till ridges which lie between the Valparaiso system and the lake.

Hickory Creek, a southern tributary entering the St. Joseph about 6 miles above its mouth, takes a direct course from the Valparaiso morainic system northwestward through the outer till ridge, but is prevented from passing directly into the lake by Covert Ridge; the creek accordingly follows the ridge in a course east of north and discharges into the St. Joseph River.

Two eastern tributaries of the St. Joseph are worthy of note. Pipestone Creek, a small tributary entering about 12 miles above the mouth of the river, drains a small lowland tract between two members of the Valparaiso morainic system, in eastern Berrien County. Dowagiac River, which enters the St. Joseph at Niles, as already noted, drains a gravel plain lying outside the Valparaiso system. An eastern branch of the same river drains a lowland tract between two Saginaw moraines in northwestern Cass County, but breaks through the western moraine to enter Dowagiac River near Dowagiac.

PAWPAW RIVER.

Pawpaw River has its headwaters in swampy plains lying east of the limits of the Valparaiso morainic system (see Pl. XV). The several headwater streams unite before reaching the Valparaiso system. The stream then passes westward in a somewhat winding course among its ridges and hills, emerging from it near Hartford, but following its inner border nearly to its junction with St. Joseph River. No important tributaries are

received after the stream enters the Valparaiso system, and it drains only a narrow strip scarcely 6 miles in average width. As above noted, it enters the St. Joseph River within a mile of the lake, and the two drainage systems are, therefore, nearly distinct.

BLACK RIVER.

Three nearly distinct drainage systems, known as North, Middle, and South Black rivers, drain a district in southwestern Allegan and northwestern Van Buren counties lying west of the Valparaiso morainic system. They unite before passing through Covert Ridge, and the united stream enters the lake at South Haven. The north branch leads westward from the "Pine Plains" to Covert Ridge, and there is deflected southward. Middle branch takes a nearly direct westward course from the "Pine Plains" to its junction with the north branch. The south branch is deflected northward in its lower course along the east border of Covert Ridge.

KALAMAZOO RIVER.

This stream, with a drainage area nearly as large as the St. Joseph River, has been deflected at several points by morainic ridges formed by the Saginaw lobe, but the lower course through the Valparaiso morainic system and districts to the west is somewhat direct. This lower course was opened after the ice sheet withdrew from the Valparaiso system. The discharge during the occupancy of this morainic system was apparently southward into the St. Joseph River. The peculiar complications of its history can only be appreciated after a description of the moraines of the Saginaw lobe. This will appear in a separate report now in preparation.

The Kalamazoo River receives only one important tributary in the district west from the Valparaiso morainic system. This tributary—Rapid River—drains a narrow belt in the northern part of Allegan County, extending from the east border of the Valparaiso system westward through the inner members of that system and across the "Pine Plains" to the outer border of Covert Ridge, where it unites with the Kalamazoo River (see Pl. XV).

CHAPTER XIII.

AVERAGE THICKNESS OF THE DRIFT IN ILLINOIS.

The region under discussion is one which may perhaps furnish a more complete series of data concerning the thickness of the drift than any region of equal size yet studied. It is especially favorable, not only because of the large number of sections of borings obtained, but also because of the comparative smoothness of the region, an estimate of average thickness being more readily obtained in a comparatively plane region than in a very hilly one.

The inequalities of the rock surface, as indicated above, are sufficient to give the drift considerable variation in thickness, for in much of the region the amount of drift is sufficient to fill the valleys or basins nearly to a level with the uplands, only the most prominent parts of the uplands rising above the general level of the drift surface.

The thickness of the drift also varies because of aggregation in morainic ridges, there being several prominent morainic belts in which the thickness is as much greater than that of the bordering plains as the measure of the relief of the moraines. The inequalities in thickness resulting from morainic accumulations are, however, much less than those resulting from variations in the altitude of the underlying rock, being seldom greater than 100 feet and often but 40 to 50 feet, while variations due to inequalities of the rock surface often reach 200 feet and may in places exceed 300 feet.

In a general sense it is true that in the portions of this region where but a single ice invasion has occurred the drift is thinner than where there has been a succession of invasions. Thus the southeastern, southern, and western portions show thinner deposits of drift than the central and northeastern. Yet extensive areas of comparatively thin drift occur in the northeastern portion on the borders of the Kankakee River and in the vicinity of the Chicago Outlet, i. e., in places where the number of invasions has been greatest.

There are two quite different methods by which the thickness of the drift may be estimated. The first is that employed some years ago by Chamberlin and Salisbury, which is based upon a comparison of the Driftless Area of southwestern Wisconsin with drift-covered areas on its borders.[1] The second is based upon wells or other borings and upon rock outcrops within the drift-covered areas. By either method only a rude approximation can be expected. In comparing drift-covered areas with the Driftless Area by the first method, some allowance must be made for departures within the drift-covered areas, from the type or types of topography exhibited in the Driftless Area. A region underlaid by shale is likely to have a topography somewhat different from one underlaid by limestone or sandstone, while among the several classes of limestone and sandstone much variation in topography may be found. To make discriminative estimates it is necessary to have a fair acquaintance with the several types of topography likely to be encountered within a given drift-covered area, as well as with the types found in the Driftless Area. Such an estimate will also be made more reliable through an acquaintance with the distribution of the main preglacial lines of drainage in the drift-covered area under investigation and the extent of each preglacial watershed. In an estimate based upon borings and outcrops there is room for much error, since they may inadequately test the thickness of the drift. Indeed, it is to be expected that there will be a larger number of outcrops and a greater proportion of borings which reach rock along the line of the preglacial ridges than along the preglacial valleys, especially where the drift has filled the valleys to the level of the ridges. By employing both methods the results are more likely to be reliable than by either method alone. The borings throw some light upon the preglacial topography and thus help in an estimate in which preglacial topography is made the main basis of calculation; while in an estimate based largely upon borings and outcrops a knowledge of the topography of neighboring driftless tracts is of great value. The data from well borings and the results of estimates based upon them are first presented. These results are then considered in the light of an estimate based upon the requirements of the topography.

The thickness of the drift has been ascertained at 1,339 points within the district covered by the Illinois lobe, of which 1,179 are within the State of

[1] See Sixth Ann. Rept. U. S. Geol. Survey, 1884-85, pp. 257-258.

Illinois. The estimates of average thickness are restricted to Illinois, inasmuch as the data collected there are fuller than in portions of neighboring States covered by the Illinois lobe. It is also a geographic unit to which the addition of the neighboring districts would be of no advantage. Furthermore, the amount of drift in these neighboring districts apparently differs so little from that of the adjacent portions of Illinois that the result would not be materially affected by including them in the calculation. The greater part of the borings upon which these computations are based are presented in the detailed discussion of wells below, while their relative frequency is shown in the accompanying map (Pl. XX).

If the points at which the thickness of drift has been determined were distributed uniformly over the region, it would be an easy matter to ascertain the average thickness, but it so happens that in some parts of the region the thickness has been tested at much more frequent intervals than at other parts. This necessitates a discriminative averaging, by which a district having many borings shall not be made of undue importance in determining the average for the State. For example, 254 of the 1,179 borings are found in five counties of northeastern Illinois, bordering the Kankakee River and Chicago Outlet, and represent an average area of only 16 square miles for each boring, while the average for the State is 45 square miles for each boring. In the remaining area occupied by the Wisconsin drift, there are only 233 borings and each boring represents an average area of 61⅓ square miles. In the portion outside the Wisconsin drift, the district north of Green River Basin has one boring for every 36 square miles; that south of Green River Basin one boring for 76.2 square miles; that between the Illinois and Kaskaskia one boring for 61.1 square miles, and that east of the Kaskaskia one boring for 78 square miles. In view of these differences it was decided to make an average of townships since they have uniform areas. This was done by averaging the wells entering rock in each township and dividing the sum of the averages for each township by the number of townships in which rock is struck. This method seems preferable to an average by counties (which was the first method attempted), since it is an average of small areas of uniform size and includes only the townships in which rock has been struck. It is found that 644 townships are represented out of a total of 1,474 townships in the glaciated portion of the State, and

MAP OF ILLINOIS
Showing distribution of wells
BY FRANK LEVERETT
1898

the average thickness for each township is 77.9 feet. In making the estimates care has been taken to avoid duplications; thus where several borings have been made on a single square mile which differ very little in distance to rock they are considered as one boring. If, however, borings in close proximity show a wide difference, they are each included in the computation.

After averaging the drift by townships the question was considered whether the townships in which rock has been struck fairly represent the thickness of the drift. This involved the consideration of their distribution in reference to moraines and in reference to preglacial valleys, both being lines where the drift has exceptional thickness. It was found that the moraines have been about as thoroughly tested as the tracts of thinner drift separating them, but an examination into the distribution along preglacial valleys has led to the conclusion that they are not adequately represented. Of the 1,179 borings which reach rock, 1,065, or fully 90 per cent, enter it near the level of the preglacial uplands, while only 114, or scarcely 10 per cent, pass markedly below the general level of those uplands before striking rock. It is difficult to decide upon the portion of the surface to be included in the valleys, especially if their intricate network of tributaries is included, but it may confidently be placed at not less than 30 per cent; possibly it may reach 50 per cent. Upon computation it is found that the average depth to rock of the borings along preglacial valleys is 172.44 feet, while the depth of those on the uplands is 67.87 feet. If the uplands comprise 70 per cent of the glaciated portion of Illinois and the preglacial valleys 30 per cent, the average thickness of drift will be 99.23 feet. If the uplands comprise 60 per cent and the valleys 40 per cent, the average will be 109.7 feet. If the uplands comprise only 50 per cent and the valleys 50 per cent, the average will be 120.15 feet. By this method of computation, therefore, the thickness appears to be not less than 99 feet, and it may be 120 feet or even more.

The thickness is on the whole greater within the area covered by the Wisconsin drift than in other portions of the State. Of the 487 borings within that area which reach rock, the average drift thickness is 121 feet. Of these borings only 52, or about 10 per cent, have struck preglacial valleys. The borings on the preglacial uplands enter rock at an average depth of 109.7 feet, while those along preglacial valleys average 221 feet to the

rock. Of the 18,000 square miles covered by the Wisconsin drift, there are about 4,000 square miles in which the thickness is much below the average. This comparatively thin drift is found in five counties which border the Kankakee River and the Chicago Outlet, viz, Kankakee, Cook, Will, Grundy, and Lasalle counties. There are 254 borings in these counties which enter rock at an average depth of only 68.8 feet. Of these 243 are on preglacial uplands and enter rock at an average depth of only 63.8 feet, while 11 along preglacial valleys average 179 feet to rock.

If now the Wisconsin drift area be corrected for the imperfect representation of preglacial valleys, in accordance with the corrections applied to the whole State, it is found that the average thickness, on a basis of 30 per cent being in valleys, would be 143 feet; on a basis of 40 per cent in valleys the average will be 154 feet, and on a basis of 50 per cent in valleys it will be 165 feet. The general average of the Wisconsin drift is thus 40 to 45 feet above that for the entire State.

Turning to the Iowan drift, there is found a markedly greater amount of drift in the counties lying east of Rock River than in those west of that stream. The few borings which have been made indicate that the thickness in the former district will average not less than 100 feet, while in the latter it is but 50 to 75 feet. The thinness of the Iowan drift near its margin is perhaps due in the main to the withdrawal of the loess which apparently has been derived in large part from the Iowan ice sheet, but has been scattered widely outside the limits of the Iowan till.

In the portion of the State lying outside the limits both of the Iowan and the Wisconsin till sheets—i. e., the portion occupied by Illinoian till and loess—there is a marked variation in the thickness of the drift. The thinnest drift of the State is found in the district lying east of the Kaskaskia, a district having an area of nearly 11,000 square miles. Of the 138 borings reported which reach rock in that district, 128 are found on preglacial uplands, and enter rock at an average depth of only 20.4 feet. The 10 borings entering rock along preglacial valleys show an average drift thickness of 106 feet. In the remainder of the Illinoian drift area the borings enter rock at an average depth of about 55 feet, including 52 valley borings. The average thickness on the preglacial uplands of that region scarcely exceeds 40 feet.

The following tabular statement sets forth the proportion of reported borings between each 100 feet within the entire district covered by the Illinois lobe, and includes both those which reach rock and those which do not.

	Number.
With 400 feet or more	4
With 300 to 400 feet	18
With 200 to 300 feet	138
With 100 to 200 feet	698
With less than 100 feet	2,251
Total	3,109

After the estimates just recorded were completed, the thickness of drift in Illinois was computed on the basis of the requirements of the topography, the data obtained by Chamberlin and Salisbury in the Driftless Area serving as a guide. The investigations in the Driftless Area led to the opinion that 150 to 200 feet of drift is necessary to fill the valleys up to the level of the divides, all the summits of the ridges being still left bare, while 300 feet would be necessary to bury the region as deeply as in the heavy drift regions of the four adjoining States.[1]

Upon turning to Illinois, it is found that the drift in places has filled the valleys completely and brought the surface up to a level perhaps 100 feet or more above the summits of the ridges. In much more extensive districts it has barely filled the valleys, while in fully half the State it has fallen short of filling the valleys, the amount in the different localities being two-thirds, one-half, one-third, or one-fourth as great as is necessary to completely fill the valleys.

It is estimated that there may be about 4,160 square miles along the bulky moraines of the Wisconsin drift in which the average thickness reaches 300 feet; but in the greater part of the Wisconsin drift area it can scarcely exceed 200 feet, for the filling extends but little above the level of the rock divides. There is estimated to be 10,975 square miles in which the average thickness may reach 200 feet, this district lies mainly within the Wisconsin drift but extends beyond this drift down the Illinois Valley through Mason and the adjoining portion of Logan County into Cass County. The area of Iowan drift in eastern Winnebago, Boone, and neighboring portions of McHenry and Kane counties may possibly have 150

[1] Sixth Ann. Rept. U. S. Geol. Survey, pp. 257–258.

feet of drift, and so many portions of the Illinoian drift area in Western Illinois, for they are built up about to the level of the summits of the rock ridges. It is estimated that such areas embrace only about 3,550 square miles. More than half the Illinoian drift area, embracing about 19,275 square miles, appears to have been filled to about two-thirds the capacity of the preglacial valleys and to have perhaps 100 feet of drift. There is an area of nearly 7,000 square miles lying mainly in southern Illinois but embracing also portions of Stevenson, Winnebago, Ogle, Carroll, and Jo Daviess counties, in northwestern Illinois, where the average thickness can scarcely reach 50 feet, the valleys being filled only to one-third or one-fourth their full capacity. There remain about 8,000 square miles in south-central and southwestern Illinois in which it is somewhat greater than in the districts just mentioned and may average 75 feet.

Summing up the above estimates in a tabular statement and averaging the results for the State, we have the following table:

Distribution, by depths, of glacial drift in Illinois.

Area.	Depth of drift.	Depth if distributed over entire State.
Square miles.	*Feet.*	*Feet.*
4, 160	300	23. 50
10, 975	200	41. 35
3, 550	150	10. 04
19, 275	100	36. 32
8, 190	75	11. 57
6, 924	50	6. 52
53, 074	....	129. 30

The above computations are necessarily less exact than those based upon borings, but the method may prove helpful in supplementing one based entirely on borings. It is some satisfaction to find that the results obtained by the two methods are not so widely discordant as to leave doubtful the general average thickness. As the computation just made represents the maximum estimate of thickness, it should be compared with the highest of the corrected estimates from borings. With this it is in essential agreement, being but 9 feet higher. The average thickness for

the State may safely be placed at not more than 130 feet and not less than 100 feet; probably it lies not far from midway between these amounts, or 115 feet.[1]

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[1] In the above estimates everything which overlies the rock has been included, not only glacial drift, but residuary clay, alluvium, and loess. In order to ascertain the proportion of till, a careful computation has been made from the records of 1,687 borings obtained within the the area covered by the Illinois lobe. These give the following results:

	Per cent.
Till, including all glacial clays	69.38
Sand, gravel, and alluvium	25.25
Loess and associated silts	4.25
Buried soil, residuary clay, etc	1.12
Total	100.00

In this computation it is probable that the amount of residuary material is underestimated, since it is only occasionally recognized in borings.

CHAPTER XIV.

WELLS OF ILLINOIS.

INTRODUCTION.

In the Seventeenth Annual Report of this Survey the writer has presented a paper on the "Water resources of Illinois," in which the wells are discussed in a general manner in connection with other water resources. The data concerning artesian wells and the wells affording supplies for cities and villages are tabulated in that paper, but a large number of wells which do not admit of ready classification were necessarily omitted. The present discussion aims to present all the reliable records collected in the State which throw light upon the formations penetrated and the character of the water supply.

CLASSIFICATION OF UNDERGROUND WATERS.

The classification of underground waters given below seems to include the most important phases or classes of subterranean distribution to be found in this region. It has already been presented in nearly its present form by the writer in the Eighteenth Annual Report. In nearly all cases it is not difficult to decide from the description to which class a given well should be referred, and it has scarcely seemed necessary, in the detailed discussion which follows, to group the wells in classes. They are instead taken up by counties. However, a tabulated statement has been prepared setting forth the use made of the several classes of wells as sources for city water supply.

The following are the principal classes of underground waters:

Class 1.—Ground water, supplied by direct percolation of the rainfall into the soil and substrata, and subject to but little lateral transmission and little hydrostatic pressure. The water level rises and falls with the degree of saturation by rains.

Class 2.—Waters in close association with streams, as in valley bottoms, in which lateral transmission is great and hydrostatic pressure is small. It

differs from the former class not only in the great lateral transmission, but also in being fed partly by stream percolation. The level rises and falls with that of the neighboring streams. This class should perhaps include the waters of sand plains and gravel plains which have no surface streams traversing them, for waters in such plains usually have great lateral transmission and but little hydrostatic pressure.

Class 3.—Water included in porous beds of glacial drift or other nonindurated formations lying beneath impervious beds but without strong hydrostatic pressure. Such water is supplied from more or less distant absorption areas and is less directly influenced by rainfall than the preceding classes.

Class 4.—Water with strong hydrostatic pressure included in porous beds of glacial drift or of alluvium. This includes two subclasses, viz: (*a*) Flowing wells; and (*b*) wells in which water rises nearly to the surface. Subclass (*a*) embraces wells to which the name "artesian" is considered applicable, while the term is not extended to wells of subclass (*b*).

Class 5.—Streams in caves and subterranean passages in the rock, fed by sink holes and brooks and also by direct percolation from ground water.

Class 6.—Rock water with but little current and slight hydrostatic pressure.

Class 7.—Rock water under strong hydrostatic pressure. This includes two subclasses, viz: (*a*) Waters which overflow when tapped; (*b*) waters which rise nearly to the surface. Subclass (*a*) embraces wells to which the term "artesian" has long been applied, and it seems a convenient term for use if properly restricted, but its extension to nonflowing wells tends to mislead and confuse those interested in obtaining a flow of water.[1]

Discrimination in selection of records.—It should not be inferred that the average depth of the wells reported in the ensuing discussion represents the average of all the wells that the region affords. Attention is directed chiefly to the deeper wells, since they throw more light than the shallow ones upon the structure of the formations penetrated and upon the supplies of water. The great majority of wells in the State are the seep or ground-water wells (class 1). They are sunk to depths of but 10 to 20 feet. In seasons when rainfall is normal or excessive such wells supply the needs of the residents,

[1] Compare Chamberlin, Fifth Ann. Rept. U. S. Geol. Survey, p. 131.

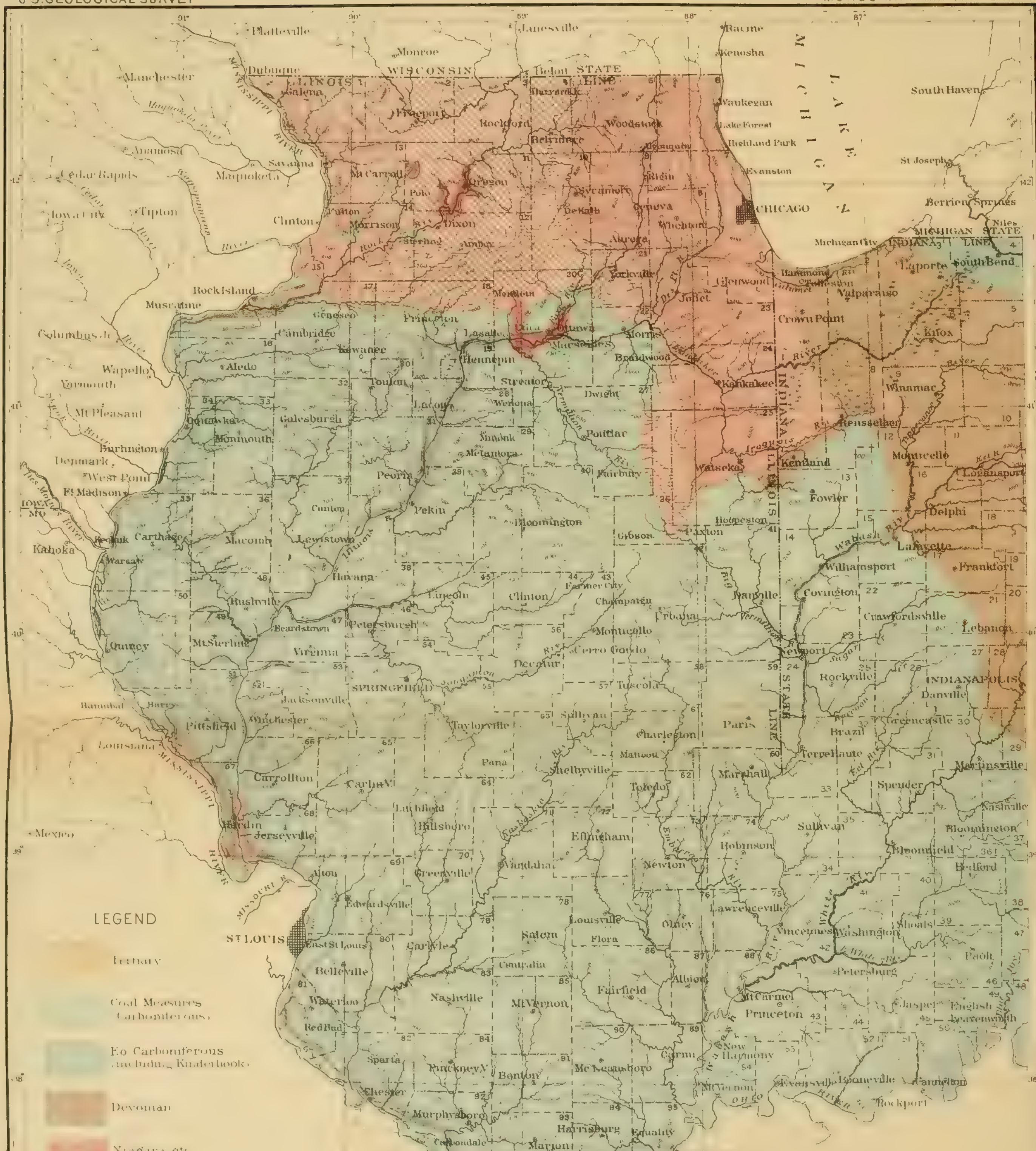
but in seasons when the rainfall is deficient many of them fail, or yield but a small amount of water. The wells here recorded are generally those which afford a supply of water in seasons of drought as well as in rainy seasons.

The well records have been obtained largely from the drillers. In some cases there is uncertainty as to the reliability of such records, but as a rule the drillers are sufficiently careful in their observations to warrant the acceptance of their statements. Records have, in many cases, been obtained from the owners of the wells, who were present during their excavation and often assisted in making the wells. The village wells have usually been recorded carefully during the excavation or drilling, and thus have a value above those whose records are given from memory. The writer has rejected such well records as are thought to be unreliable, and has endeavored to reduce errors to a minimum. It is thought that the records here presented contain few serious errors, and that the general exposition of the subject and general conditions for obtaining water are set forth with a fair degree of accuracy. The published well records in the Geology of Illinois are also included in this report and duly accredited.

THE GEOLOGIC FORMATIONS.

Since many of the wells enter rock, a map of the geologic formations is here introduced (Pl. XXI) which was prepared by the writer to accompany a paper in the Seventeenth Annual Report. It follows in the main Prof. A. H. Worthen's map of Illinois, published in 1875, to accompany Vol. VI of the Geology of Illinois, but a few corrections have been made in northern Illinois based upon observations by Mr. Oscar Hershey and the writer. The portion covering western Indiana is based upon Dr. A. J. Phinney's map of Indiana, published by this Survey in 1890.[1] The limestone formations of the northern and western parts of Illinois and the sandstones and sandy shales of the southern and southeastern parts are extensively utilized as a source for ordinary wells for household use. The limestones are also a source for artesian wells or deep wells having strong hydrostatic pressure. A few artesian wells obtain water from the sandstones of southern Illinois. In northern and western Illinois the St. Peter and Potsdam sandstones are the sources of numerous artesian wells. The

[1] Eleventh Ann. Rept. U. S. Geol. Survey, Pl. LXIII.



Counties in ILLINOIS

1 JO DAVIESS
2 STEPHENSON
3 WINNEBAGO
4 BOONE
5 MC HENRY
6 LAKE
7 COOK
8 DUPAGE
9 KANE
10 DEKALB
11 OGLE
12 LEE
13 CARROLL
14 WHITESIDE
15 ROCK ISLAND
16 MERCER
17 HENRY
18 BUREAU
19 PUTNAM
20 LASALLE
21 KENDALL
22 GRUNDY
23 WILL
24 KANKAKEE
25 IROQUOIS
26 FORD
27 LIVINGSTON
28 MARSHALL
29 WOODFORD
30 STARK
31 PEORIA
32 KNOX
33 WARREN
34 HENDERSON
35 HANCOCK
36 MC DONOUGH
37 FULTON
38 MASON
39 TAZEWELL
40 MC LEAN
41 VERMILION
42 CHAMPAIGN
43 PIATT
44 DEWITT
45 LOGAN
46 MENARD
47 CASS
48 SCHUYLER
49 BROWN
50 ADAMS
51 PIKE
52 SCOTT
53 MORGAN
54 SANGAMON
55 CHRISTIAN
56 MACON
57 MOULTRIE
58 DOUGLAS
59 EDGAR
60 CLARK
61 COLES
62 CUMBERLAND
63 SHELBY
64 MONTGOMERY
65 MACOUPIN
66 GREENE
67 CALHOUN
68 JERSEY
69 MADISON
70 BOND
71 FAYETTE
72 EFFINGHAM
73 JASPER
74 CRAWFORD
75 LAWRENCE
76 RICHLAND
77 CLAY
78 MARION
79 CLINTON
80 ST CLAIR
81 MONROE
82 RANDOLPH
83 WASHINGTON
84 PERRY
85 JEFFERSON
86 WAYNE
87 EDWARDS
88 WABASH
89 WHITE
90 HAMILTON
91 FRANKLIN
92 JACKSON
93 WILLIAMSON
94 SALINE
95 GALLATIN
96 HARDIN
97 POPE
98 JOHNSON
99 UNION
100 ALEXANDER
101 PULASKI
102 MASSAC

AND INDIANA

1 LAKE
2 PORTER
3 LAPORTE
4 ST JOSEPH
5 MARSHALL
6 STARKE
7 NEWTON
8 JASPER
9 PULASKI
10 FULTON
11 CASS
12 WHITE
13 BENTON
14 WARREN
15 TIPPECANOE
16 CARROLL
17 CLINTON
18 HOWARD
19 TIPTON
20 HAMILTON
21 BOONE
22 MONTGOMERY
23 FOUNTAIN
24 VERMILION
25 PARKE
26 PUTNAM
27 HENDRICKS
28 MARION
29 JOHNSON
30 MORGAN
31 OWEN
32 CLAY
33 VIGO
34 SULLIVAN
35 GREENE
36 MONROE
37 BROWN
38 JACKSON
39 LAWRENCE
40 MARTIN
41 DAVIESS
42 KNOX
43 GIBSON
44 PIKE
45 DUBOIS
46 ORANGE
47 WASHINGTON
48 FLOYD
49 HARRISON
50 CRAWFORD
51 PERRY
52 SPENCER
53 WARRICK
54 VANDERBURG
55 POSEY

GEOLOGIC FORMATIONS OF ILLINOIS AND WESTERN INDIANA

Compiled from Worthen's map of Illinois 1875 and Phinney's map of Indiana, U S G S 1890

BY FRANK LEVERETT

1898

Lower Magnesian limestone is also used for artesian supply. Portions of the Coal Measures yield brackish water, and for this reason they have not been extensively utilized for water supply. In some localities, however, it has been found necessary to make use of these formations because of no adequate supply from the drift or overlying rocks. In such places the presence of beds yielding comparatively fresh water has been made known. In the detailed discussion which follows, the degree of development of the several rock formations is set forth.

ATTITUDE OF THE STRATA.

The attitude of the strata is very favorable for producing a strong hydrostatic pressure in deep wells throughout much of the State. A north-to-south section shows a gradual southward dip of the formations (see figs. 7 and 8), terminated at the south by an axis of upheaval which, as above noted, leads eastward across the southern end of the State from Grand Tower to Shawneetown. The descent probably amounts to 2,500 or 3,000 feet in the 350 miles from the north to the south end of the State. There are slight undulations carrying the strata up or down 100 to 200 feet or more from a uniform grade, but so far as known no prominent west-to-east axis of upheaval crosses the State north of the one just noted, none adequate to prevent the southeast passage of the water.

East-to-west sections are less uniform in the inclination of strata than the north-to-south sections. Sections across the northern part of the State present two blocks of strata, each dipping gradually to the east, separated by an abrupt fold or line of disturbance (see fig. 9). At this fold the block on the east rises abruptly several hundred feet above the neighboring portion of the western block. It is along this line of disturbance that the St. Peter and Lower Magnesian strata are brought to view on the Illinois and Rock rivers and on Elkhorn Creek. Its trend from the Illinois River northward is about southeast to northwest. Sections in the lead region indicate that it continues in subdued form some distance into southwestern Wisconsin. Its southward continuation from the Illinois is readily traceable as far as Livingston County by disturbances shown in coal shafts, as noted by the Illinois survey. Farther south its course is less definitely known.

There is, over much of western Illinois, a gradual descent from the western border of the State to this line of disturbance. In the latitude of

Peoria it averages about 7 feet per mile, and is not greatly different in portions of the State farther north. The eastward descent across western

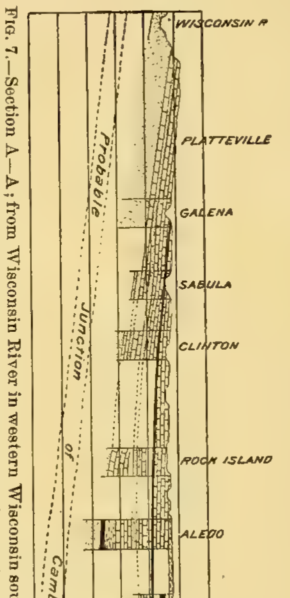


FIG. 7.—Section A—A; from Wisconsin River in western Wisconsin southward to Cap au Grès, Illinois. This section shows a line through a region where wells are very successful. Northward from Aledo the section shows but one shale bed (the Hudson River), and this is wanting north from Galena. But south from Aledo the Kinderhook and Coal Measures shales comprise a considerable portion of the section. Vertical scale is 40 times the horizontal.

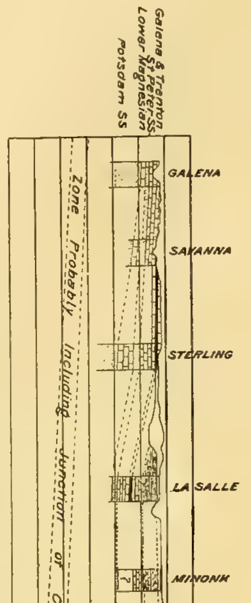


FIG. 8.—Section B—B; from Galena to Olney, Illinois. This section leads through the deep part of the Coal Measures basin from Lasalle to Olney. Wells are successful from Minonk northward. Vertical scale is 40 times the horizontal.

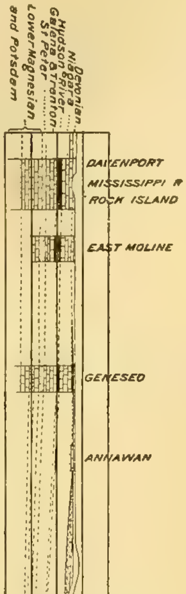


FIG. 9.—Section C—C; from Davenport, Iowa, to Joliet, Illinois. This section shows the monoclinal fold which passes just east of Lasalle, with the nearly horizontal blocks on either side. Vertical scale is 20 times the horizontal.

Illinois appears to continue gradual as far south as the Cap au Grès upheaval, near the mouth of the Illinois, and, so far as known to the writer,

there is no marked disturbance along the Mississippi north from that point. From the Cap au Grès disturbance southward to the Ozark Ridge, in southern Illinois, a different field is found. Disturbances are frequent along the Mississippi. There is also in this district a more abrupt descent in the floor of the Coal Measures within a few miles east of the Mississippi. Thus, in passing from the east bluff of the river in western St. Clair County to Belleville a descent of 650 feet is made within a distance of 10 miles.

ESSENTIAL CONDITIONS FOR ARTESIAN WELLS.

Since the essential conditions for obtaining artesian wells have been discussed at some length by Prof. T. C. Chamberlin in a report of this Survey,[1] only a brief outline of their conditions is here attempted. The essential conditions for artesian wells are: (1) A suitable exposure of a porous rock in a humid region, i. e., a favorable absorbing area; (2) the extension of the porous bed from the absorbing area out underneath regions having a lower altitude, i. e., a favorable transmitting area; (3) a partial or full obstruction to the escape of the waters at a lower level than the absorbing area. The porous rock is usually confined between beds which are less porous and which act as a partial or complete obstruction to the escape of the waters. It is not necessary, however, that these beds should be perfectly water-tight; indeed, such is rarely the case. It is only necessary that the confining beds should be such as to prevent most of the water from escaping. In some cases the water contained in semiporous beds overlying the porous rock aids in preventing the escape of water from the porous bed at points between the absorbing area, or fountain head, and the well. In connection with this condition Professor Chamberlin remarks:[2]

> I conceive that one of the most favorable conditions for securing a fountain is found where thick, semiporous beds, constantly saturated with water to a greater height than the fountain head, lie upon the porous stratum and occupy the whole country between the well and its source. This is not only a good but an advantageous substitute for a strictly impervious confining bed. Under these conditions limestone strata reposing on sandstone furnish an excellent combination.

This condition prevails extensively in northern Illinois. The absorbing area for the artesian waters of northern Illinois is found in southern Wisconsin, the porous rock thence dipping southward to northern Illinois.

[1] Fifth Ann. Rept. U. S. Geol. Survey, 1885, pp. 131–173.
[2] Loc. cit., p. 140.

Between this absorbing area and the wells is a district in which the porous bed is overlain by limestone or semiporous rock, and also by drift beds, which afford much opportunity for absorption of water. These overlying beds, however, have altitudes fully as great as portions of the absorbing area, and hence, when filled with water, the downward pressure equals or exceeds that of the upward pressure of water from the porous beds, and thus they prevent escape as effectually as a series of impervious beds. The variability of head displayed by wells in northern Illinois which obtain their main supply from the St. Peters formation is probably largely due to the influx of water from overlying beds in the district between the fountain head and the well. The main absorbing areas for the Potsdam and St. Peter formations are shown in Pl. XXII, which is compiled chiefly from State geological maps and was first published by the writer in the Seventeenth Annual Report of this Survey.

A topographic map of the St. Peter sandstone, showing also the distribution of artesian wells and deep borings and of the principal areas where flowing wells are obtained from the drift, is presented in Pl. XXIII, a map already published in the Seventeenth Annual Report. The three sections in figs. 20, 21, and 22 illustrate the above statements concerning the attitude of the rock formations and correspond to the lines A—A, B—B, and C—C on Pl. XXIII. The data used in figs. 7 and 8 are largely obtained from records of wells collected by the writer, but some of the data are from a report by Daniel W. Mead, bearing upon the hydrogeology of the Mississippi Basin.[1] The data in fig. 9 are largely based upon a special study by Prof. J. A. Udden of a line leading from Rock Island eastward across Illinois, which was made for the Illinois Board of World's Fair Commissioners.[2] It brings out clearly the monoclinal fold separating the two blocks of eastward-dipping strata just noted. For a more complete discussion of artesian-well conditions in Illinois, reference may be made to the report by the writer contained in the Seventeenth Annual Report of this Survey. Many records of wells appear in the detailed discussion below.

[1] Hydrogeology of the Upper Mississippi Valley and some of the adjoining Territory, by Daniel W. Mead, C. E.: Jour. Assoc. Eng. Soc., Vol. XIII, No. 7, July, 1894. 68 pages, with 6 maps.

[2] See Final Report Illinois Board of World's Fair Commissioners, 1895, pp. 115–151.

MAIN ABSORBING AREAS FOR THE POTSDAM AND ST. PETER FORMATIONS

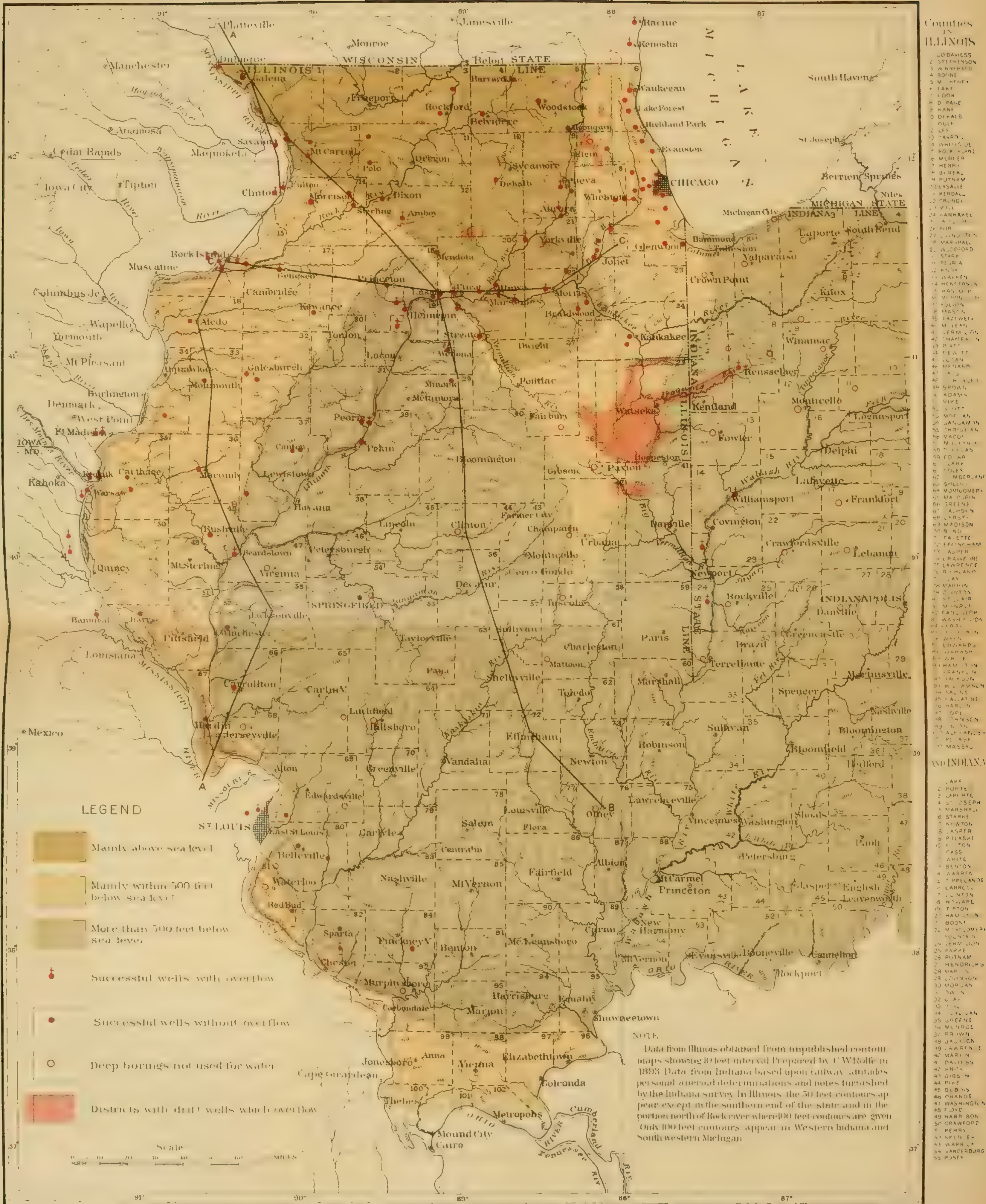
COMPILED CHIEFLY FROM STATE GEOLOGICAL MAPS

BY FRANK LEVERETT 1896.

Scale

25 0 25 50 75 100 MILES

JULIUS BIEN & CO N.Y.



HYPSOGRAPHIC MAP OF THE ST. PETER SANDSTONE OF ILLINOIS AND WESTERN INDIANA

Showing distribution of artesian wells and deep borings

BY FRANK LEVERETT

1898

MAP OF ILLINOIS AND WESTERN INDIANA

Showing the relation of the Glacial drift to the ordinary wells

BY FRANK LEVERETT

1898

RELATION OF THE DRIFT TO ORDINARY WELLS.

The general relation of the drift to the ordinary wells of Illinois and western Indiana is set forth in Pl. XXIV. It will be observed that with the exception of a few counties in the northern and southern ends of Illinois the wells are largely obtained from the drift. This relation is shown in detail in the discussion which follows.

GAS WELLS.

Wells which yield an inflammable gas are found in many counties of the State, instances of which are presented in connection with the water wells. This gas in some cases appears to be derived from the decay of vegetal matter contained in the drift, either in the form of peat and muck beds or as timber scattered through the drift. It is probable, however, that the underlying rocks are an important if not the chief contributor, in which case the pressure of the gas within the drift is due to the resistance which compact drift beds offer to the escape of the gas. Not only the shales but certain limestones in this region have been found to contain gas. But it does not seem to have accumulated in such great quantities as in the gas fields of the neighboring States of Indiana and Ohio. It rarely reaches a pressure of 20 pounds per square inch.

TABULATION OF SOURCES FOR CITY WATER SUPPLY.

The following table embraces all the cities and villages in Illinois having water works whose source of supply has been ascertained. It is based, in part, upon data collected by the writer, and in part upon data found in the Manual of American Water Works for 1897.[1] Through the aid of this publication the statistics have been properly rounded out and brought down to date. In towns with the letter "M" appended the Manual of Water Works is the authority. The wells are classified according to the scheme above outlined (pp. 550–551). Many details concerning the city water supplies appear in the subsequent discussion by counties.

[1] The Manual of American Water Works, 1897, edited by M. N. Baker, Engineering News Pub. Co., New York. Contains the history and descriptions of the source and mode of supply, pumps, reservoirs, standpipes, distribution systems, pressures, consumption, revenue and expenses, cost, debt, and sinking fund, etc., of the water works of the United States and Canada.

Sources of water supply for towns in Illinois.

Town.	Population in 1890.	Source.
Aledo	1,601	Rock, class 7.
Alexis (M)	562	Drift, class 3.
Algonquin	300	Springs.
Alton	10,294	River.
Amboy	2,257	Rock, class 7.
Arcola	1,733	Drift, class 3.
Atlanta	1,178	Drift, class 3.
Aurora	19,688	Rock, class 7.
Austin	4,051	Rock, class 7.
Avon (M)	692	Rock, class 6.
Barry	1,354	Rock, class 7.
Batavia (M)	3,543	River (?).
Beardstown	4,226	Drift, class 4.
Belleville	15,361	Creek.
Belvidere	3,877	Rock, class 7.
Bement	1,129	Drift, class 3.
Bloomington	20,484	Drift, class 4.
Buckley (M)	433	Drift, class 4.
Buda	990	Rock, class 7.
Bushnell	2,314	Drift, class 3.
Cabery (M)	342	Well, 240 feet, class 3 (?).
Cairo	10,324	River.
Cambridge (M)	940	Deep well, class 7 (?).
Canton	5,604	Rock, class 7.
Carbon Hill (M)	(?)	Rock, class 7.
Carlinville	3,293	Creek.
Carlyle	1,784	River.
Carmi (M)	2,785	River.
Carrollton	2,258	Rock, class 7.
Carthage	1,654	Rock, class 7.
Centralia	4,763	Creek.
Chadwick	(?)	Rock, class 6.
Champaign	5,839	Drift, class 4.
Charleston	4,135	River.
Chatsworth	827	Drift, class 3.
Chenoa	1,226	Rock, class 6.
Chicago	1,099,850	Lake.
Chicago Heights	(?)	Rock, class 6.
Chillicothe	1,632	Alluvium, class 2
Cissna Park (M)	(?)	Drift, class 4.
Clayton (M)	1,033	Rock, class 6.
Clinton	2,538	Drift, class 3.
Collinsville	3,498	Rock, class 7.

Sources of water supply for towns in Illinois—Continued.

Town.	Population in 1890.	Source.
Crescent (M)	(?)	Drift, class 4.
Danvers	505	Drift, class 3.
Danville	11,491	River.
Decatur	16,841	River.
Dekalb	2,579	Rock, class 7.
Delavan	1,176	Drift, class 3.
Des Plaines (M)	986	Rock, class 6.
Dixon	5,161	Rock, class 7.
Downers Grove (M)	960	Deep well, class (?).
Dundee	(?)	Springs.
Dwight	1,354	Drift, class 4.
Earlville	1,058	Rock, class 6. Drift, class 4.
East Dubuque	1,069	Rock, class 7.
East St. Louis	15,169	River.
Effingham	3,260	River.
Elgin	17,823	River.
Elmhurst (M)	1,050	Spring.
Elmwood (M)	1,548	Rock, class 7.
Elpaso	1,353	Drift, class 3.
Eureka	1,481	Drift, class 3.
Evanston	12,762	Lake.
Fairbury	2,324	Rock, class 7.
Farmer City	1,367	Drift, class 4.
Farmington (M)	1,375	Rock, class 7 (?).
Flannigan (M)	384	"Artesian well," class (?).
Forrest	1,021	Drift, class 3.
Forreston	1,118	Rock, class 7.
Freeport	10,189	Alluvium, class 2. Rock, class 7.
Fulton	2,099	Rock, class 7.
Galena	5,635	Rock, class 7.
Galesburg	15,264	Rock, class 7. Drift, class 4.
Galva (M)	2,409	Well, class (?).
Geneseo	3,182	Rock, class 7.
Geneva	1,692	Rock, class 7.
Gibson	1,803	Drift, class 3.
Gilman	1,112	Drift, class 4.
Granite (M)	(?)	River.
Grayville	1,999	River.
Greenville	1,868	Drift, class 3.
Harvey	(?)	Rock, class 7.

Sources of water supply for towns in Illinois—Continued.

Town.	Population in 1890.	Source.
Havana	2,525	Alluvium, class 2. Drift, class 4.
Hennepin	574	Rock, class 7.
Highland Park	2,163	Lake.
Hillsboro	2,500	Springs.
Hinsdale	1,584	Rock, class 7.
Hoopestown	1,911	Rock, class 7.
Ipava	667	Rock, class 7.
Jacksonville	12,935	Rock, class 7.
Jerseyville	3,207	Rock, class 7.
Joliet	23,264	Rock, class 7.
Kankakee	9,025	River.
Keithsburg	1,484	Alluvium, class 2.
Kempton (M)	201	Drift, class 3.
Kewanee	4,569	Rock, class 7.
Kirkwood (M)	949	Rock, class 6 (?).
Knoxville	1,728	Rock, class 7.
Lacon (M)	1,649	Well, class (?).
Lagrange	2,314	Rock, class 7.
Laharpe	1,113	Drift, class 3.
Lake Forest	1,203	Lake.
Lanark	1,295	Drift, class 3.
Lasalle	9,855	Rock, class 7. Springs.
Lemont	(?)	Rock, class 7.
Lena (M)	1,270	Deep well, class (?).
Leroy	1,258	Drift, class 3.
Lewiston	2,166	Alluvium, class 2.
Lexington (M)	1,187	Well, class (?).
Lincoln	6,725	Creek.
Litchfield	5,811	Creek.
Lockport	2,449	Rock, class 7.
Macomb	4,052	Rock, class 7.
Macon	819	Drift, class 3.
Mackinaw	545	Drift, class 3.
Madison	(?)	River.
Marengo	1,445	Drift, class 4.
Maroa	1,164	Drift, class 3.
Mason	1,869	Drift, class 3.
Mattoon	6,833	Drift, class 3.
Maywood (M)	2,076	Rock, class 7.
Mendon	640	Rock, class 7.
Mendota	3,542	Rock, class 7.

Sources of water supply for towns in Illinois—Continued.

Town.	Population in 1890.	Source.
Metamora	758	Drift, class 3.
Metropolis	3,593	River.
Milan	692	Rock, class 7.
Milford (M)	957	Drift, class 4.
Minonk	2,316	Rock, class 7.
Moline	12,000	River.
Monmouth	5,936	Rock, class 7.
Monticello	1,643	Drift, class 3.
Morgan Park	1,027	Rock, class 7.
Morris	3,653	Rock, class 7.
Morrison	2,088	Springs.
Morrisonville	844	Drift, class 3.
Morton	657	Drift, class 3.
Mount Carmel	3,376	Alluvium, class 2.
Mount Carroll	1,836	Rock, class 7.
Mount Morris	895	Rock, class 6.
Mount Pulaski (M)	1,357	Well, class (?).
Mount Sterling	1,655	Drift, class 3.
Mount Vernon	3,233	Impounded water.
Moweaqua (M)	848	Well, class (?).
Murphysboro	3,880	River.
Newton	1,428	River.
Nokomis	1,305	Drift, class 3.
Norwood Park	(?)	Rock, class 7.
Oak Park	4,771	Rock, class 7.
Ohio	360	Drift, class 3.
Olney	3,831	River.
Onarga	994	Drift, class 4.
Orangeville	347	Rock, class 6.
Oregon (M)	1,566	Well, class (?).
Oswego (M)	641	Well, class (?).
Ottawa	9,985	Rock, class 7.
Pana	5,077	Drift, class 3.
Park Ridge (M)	987	Rock, class 7.
Paris	4,966	Drift, class 3.
Pawpaw	(?)	Rock, class 7.
Paxton	2,177	Drift, class 4.
Pecatonica	1,059	Springs.
Pekin	6,347	Drift, class 4.
Peoria	41,024	Drift, class 4.
Peru	5,550	Rock, class 7.
Petersburg	2,342	Alluvium, class 2.

Sources of water supply for towns in Illinois—Continued.

Town.	Population in 1890.	Source.
Pinckneyville	1,298	Rock, class 7.
Pittsfield	2,295	Rock, class 7.
Plano (M)	1,825	Rock, class 7.
Pontiac (M)	2,784	River.
Princeton	3,396	Rock, class 7.
Quincy	31,494	River.
Rantoul (M)	1,074	Drift, class 3.
Riverside	(?)	Rock, class 7.
Rochelle	1,789	Springs.
Rock Falls	1,900	Rock, class 7.
Rockford	23,584	Rock, class 7.
Rock Island	13,624	River.
Roseville (M)	788	Well, class (?).
Rossville (M)	879	Well, class (?).
Rushville (M)	2,031	Springs.
Sandwich	2,516	Drift, class 4.
Savanna	3,097	Rock, class 7.
Shannon	591	Rock, class 6.
Sheffield (M)	993	Well, class (?).
Shelbyville	3,162	River.
Somonauk (M)	468	Well, class (?).
Springfield	24,963	Alluvium, class 2.
Staunton	2,209	Impounded water.
Sterling	5,824	Rock, class 7.
Stockton (M)	379	Well, class (?).
Streator	11,414	River.
Sullivan	1,468	Drift, class 3.
Sycamore	2,987	Drift, class 4.
Taylorville	2,829	Drift, class 3.
Tolono (M)	902	Well, class (?).
Urbana	3,511	Drift, class 4.
Upper Alton	1,803	Alluvium, class 2.
Vandalia	2,144	River.
Venice	932	River.
Walnut	605	Drift, class 3.
Warren	1,172	Rock, class 7.
Warsaw	2,721	Rock, class 7.
Washington	1,301	Drift, class 4.
Waterloo	1,860	Impounded water.
Waterman (M)	351	Well, class (?).
Watseka	2,017	Drift, class 4.
Waukegan	4,915	Lake.

Sources of water supply for towns in Illinois—Continued.

Town.	Population in 1890.	Source.
Waynesville (M)	368	Drift, class 3.
Wenona	1,053	Rock, class 7.
Western Springs (M)	451	Well, class (?).
Wheaton	1,622	Rock, class 6.
Wilmette	1,458	Lake.
Wilmington	1,576	River.
Winnetka	1,079	Lake.
Woodstock	1,683	Rock, class 7.
Yorkville	375	Springs.

From the above table it appears that in 69 cities and villages, or about one-third of the number in Illinois now having waterworks, the supply is obtained from rock wells either flowing (artesian) or with strong hydrostatic pressure. Of the 250,000 inhabitants of these cities and villages it is probable that more than one-half are dependent upon the public water supply. In some cities and in many of the villages a large part of the population prefer to obtain their supply from private wells or cisterns, a preference which is due in part to inability to meet the city water tax and in part to objectionable properties of the water. It should be stated, however, that throughout much of northern Illinois wells of this class furnish wholesome and very palatable water. It should be noted that wells of this kind are extensively used in various industries in the city of Chicago and in several other cities in northern Illinois, the aggregate amount of water thus obtained in Chicago approximating that furnished by the city waterworks.

In contrast with the extensive use of this class of rock wells as a city supply is the use of rock wells having weak hydrostatic pressure. Only twelve villages, with a combined population of scarcely 10,000, are known to depend upon the latter class of wells. It is possible, however, that a few others reported in the Waterworks Manual may be of that class. Such wells rarely furnish an adequate supply for a large town.

The table indicates that aside from Chicago, with its population of more than one million, there are 52 cities and villages, with a combined population of nearly 300,000, in which surface water constitutes the public supply. In Chicago the population is mainly dependent upon such water.

In the other cities, and especially in the villages, private wells and cisterns are used extensively.

Turning to drift wells, it is found that 22 cities and villages, with a combined population of about 100,000, obtain their public supply from wells in glacial drift which have strong hydrostatic pressure, many of them being flowing wells. In 38 other cities and villages, with a population aggregating about 60,000, drift wells are in use which display no marked hydrostatic pressure. There are only three cities with a population of more than 2,000 in which this class of wells constitutes the public supply, namely, Mattoon, Pana, and Paris. There are 9 cities and villages, with a combined population of about 50,000, in which the public supply is obtained from beds of alluvium. Among these cities Springfield has been included, its supply being from infiltration wells along the bank of the Sangamon River. The supply at Freeport is from wells sunk below the level of the Pecatonica River, and these may possibly be referable to class 3 rather than to this class. However, the material penetrated appears to be alluvial rather than glacial.

DETAILED DISCUSSION.

With this brief statement concerning the sources for supply in the cities of Illinois, we pass to the detailed discussion of wells by counties. The counties are taken up in the order of their numbering on Pl. XX. The discussion begins in the northern tier of counties and passes back and forth in successive tiers, terminating at the southern end of the State. The unglaciated counties at the southern end of the State are discussed as a single district and very briefly, though they present probably a greater variety of sources for water supply than almost any other area of equal size within the State. The writer's examination of that district has been too incomplete to enable him to treat adequately of its water resources.

JO DAVIESS COUNTY.

GENERAL STATEMENT.

This county is situated in the extreme northwest corner of the State and has an area of 663 square miles. The greater part lies within the Driftless Area, the glaciated portion occupying only about 100 square miles on the eastern border. The driftless portion, however, is covered with a nearly continuous sheet of loess, the thickness of which along the borders of the

Mississippi will average about 20 feet, but the average for the county will probably not exceed 10 feet. Along the Mississippi Valley on the west borders of the county there is a filling of sand and gravel about 150 feet in depth, as shown by wells on the Iowa side at Dubuque and Sabula. The tributaries of the Mississippi in this county have been silted up to a level corresponding with the filling in the Mississippi Valley. The material in these tributaries is usually a rather compact clay.

Wells in the valley of the Mississippi obtain water at depths of 20 to 40 feet without entering the rock. In the tributaries of the Mississippi a few wells obtain water from the clay deposits, but as a rule the residents depend upon either springs from the limestone bluffs or wells sunk into the rock. The wells on the uplands in the unglaciated part, and to some extent in the glaciated part, obtain their water from limestone at depths ranging from 40 feet to 150 feet or more. Usually a good supply may be obtained at less than 100 feet. In the glaciated portions of the county the drift is generally too thin to afford strong wells. There is, however, just north of Stockton a preglacial valley filled to a depth of at least 140 feet, which furnishes strong wells, some of which overflow. Throughout the county the water is of excellent quality, although very hard. The expense of sinking wells to rock being heavy, many of the residents resort to cisterns for a water supply. Impounded water is also used quite extensively to supply the stock on farms.

INDIVIDUAL WELLS.

The city water supply at Galena, the county seat, is obtained from an artesian well sunk to a depth of 1,200 feet and obtaining its supply from the Potsdam sandstone. It has a head 85 feet above the surface and a capacity estimated at 166 gallons per minute. An analysis made by the State Board of Health appears in the Seventeenth Annual Report of this Survey.[1] Wells are obtained in the vicinity of Galena from the limestone at depths of 60 to 200 feet.

At East Dubuque the town well is artesian and has a depth of 940 feet. The water is obtained from Potsdam sandstone and has a head nearly 100 feet above the surface and a capacity estimated at 420 gallons per minute. Aside from the artesian well there are a few shallow wells obtaining their supply from the gravel and sand of the Mississippi Valley.

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[1] Part II, pp. 820 and 827.

At Warren and in that vicinity the best wells are 50 to 150 feet deep and obtain water from the Galena limestone. The altitude being high (about 1,000 feet above tide), the water level in the wells is so low that windmills are usually employed to raise the water. A large proportion of the residents of the village depend upon cistern water. The Manual of American Waterworks (1897) reports that a well has recently been sunk to a depth of 900 feet which furnishes the public water supply.

No data were obtained concerning wells in other villages of the county, but a few records were obtained of wells in the glaciated portion between Stockton and Nora. These usually enter rock at 20 to 30 feet, but occasionally the drift is thicker. In the preglacial valley referred to above, which passes in an east-west course midway between these villages, several well records were obtained which are tabulated below:

Wells in a preglacial valley north of Stockton.

Owner.	Altitude (above tide).	Depth.	Head from surface.
	Feet.	*Feet.*	
Mr. Keplinger	930	50	Overflows.
A. A. Simmons	950	72	10 feet below.
Andrew Simmons	950	77	10 feet below.
Charles Kappas	950	105	10 feet below.
Theodore Hopkins	940	134	3 feet below.
W. Legrand	940	135	3 feet below.
Mrs. M. L. Crouse	940	40	Overflows.
Mrs. M. L. Crouse	930	140	Overflows.
G. W. Curtis	950	96	15 feet below.
Frank Weighers	935	110	10 feet below.
Mrs. Emily Coomler	970	135	35 feet below.
M. Werkheiser	970	85	35 feet below.
Richard Oliver	970	60	35 feet below.

The majority of the wells in the above list penetrate 50 to 70 feet of compact clay before entering a water-bearing bed, and at Mrs. Crouse's deeper well 130 feet of clay was penetrated. The last three wells in the list are situated on a low drift ridge and their sections show a larger proportion of gravel and sand than the wells on the plane surface. The strong hydrostatic pressure probably results from an absorption of water on the neighboring higher land. None of the wells in this list entered rock,

although they are all situated within 5 miles of the glacial boundary, and some of them within 2 miles.

STEPHENSON COUNTY.

GENERAL STATEMENT.

Stephenson County is situated immediately east of Jo Daviess County, on the north border of the State, with Freeport as its county seat, and has an area of 560 square miles. It is drained chiefly by Pecatonica River, which traverses its northern and eastern portions. With the exception of a few square miles in the northwest corner, this county is covered with glacial drift. The thickness of the drift is insufficient to conceal the main preglacial valleys, and extensive upland tracts have rock within a few feet of the surface. The average of the well sections reaching rock so far as collected are as follows: Forty-eight wells on uplands and slopes, 31 feet; 12 wells along preglacial valleys, 130 feet. Of these, 17 wells are in Freeport and vicinity, and average 50 feet.[1] The drift, as already noted, is frequently aggregated in small knolls and ridges having a gravelly constitution. At such places it has exceptional thickness. Aside from the preglacial valleys and the knolls and ridges just referred to, the drift is usually too thin to be depended upon as a supply for wells.

Most wells in this county, as in Jo Daviess County, obtain water from the Galena limestone at depths ranging from 30 or 40 feet up to about 200 feet. Their average depth is somewhat less than in Jo Daviess County. In the preglacial valleys and in some of the drift knolls and ridges strong wells are obtained at convenient depths—25 to 50 feet.

The highest portions of the county are very thinly coated with drift, rock usually being entered at 15 to 20 feet or less. A few instances, however, are reported in which the drift has a thickness of 80 feet or more. The lowlands are generally covered to a sufficient depth to afford an adequate supply of water without entering the rock; but there are small areas within the lowland districts in which rock is very near the surface. These contrasts in the thickness of drift, both on highland and lowland tracts, are set forth in the table of wells given below.

[1] Many of the well records were collected by Mr. Oscar Hershey during or prior to his connection with this Survey.

INDIVIDUAL WELLS.

The public water supply for the city of Freeport is obtained mainly from a series of tubular wells sunk to a depth of about 40 feet through the alluvium and possibly through glacial deposits of the Pecatonica Valley. The supply of water is derived from sand just above the rock. The Manual of American Waterworks (1897) reports that a part of the supply is from wells about 200 feet in depth, which enter the St. Peter sandstone. This sandstone is stated by Mr. Hershey to set in about 110–130 feet below the surface of the Pecatonica flood plain at Freeport.

Several private wells in Freeport have been sunk to the St. Peter sandstone, and this sandstone is occasionally encountered in wells in the north part of the county. Near Orangeville the St. Peter sandstone comes nearly to the surface. The waterworks supply for that village is from a well 142 feet in depth, which is mainly through St. Peter sandstone.

The public water supply at Lena is from a deep well, but the precise depth has not been ascertained. Rock is usually entered in that vicinity at about 15 feet.

In the vicinity of Kent rock is entered at about 30 feet. The railway well at Kent Station is 275 feet in depth and obtains its supply in limestone. The limestone ridge south of Kent has rock at surface, there being scarcely enough drift to form a soil.

The following table of wells is made up largely from data furnished by Mr. Hershey:

Table of well sections in Stephenson County, Illinois.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Baier & Ohlendorf, at Freeport.	765	240	Enters St. Peter sandstone at 167 feet; drift, 34 feet.
J. Wareham, Freeport	770	212	St. Peter sandstone at 186 feet; drift, 85 feet.
D. Hoover, Freeport	(?)	60	Depth of drift, 35 feet.
Millner's Brewery, Freeport	780	57	Strong vein of water in limestone; drift, 30 feet.
Electric light plant, Freeport	760	240	Drift, mainly loess, 30 feet.
Stover M'f'g Co., of Freeport	755	112	Enters St. Peter sandstone; drift, 100 feet.
Vinegar Works, Freeport	750	(?)	Penetrates drift 85 feet.
Triple Factories, Freeport	770	(?)	Drift, mainly loess, 38 feet.
H. S. Gochenour, Freeport	825	80	Rock entered at 6 feet.
D. Sweeny, East Freeport	760	50	Wells in East Freeport 30 to 50 feet in depth do not reach rock.

Table of well sections in Stephenson County, Illinois—Continued.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Sec. 23, T. 27, R. 9 E	750	30	Rock not entered.
Sec. 30, T. 27, R. 9 E	765	82	Enters rock at 62 feet.
W. H. Fulton, Rock Grove	(?)	65	Rock entered at 20 feet.
Davis Station	900	80	Drift in places, 80 feet.
Sec. 25, T. 27, R. 8 E	825	72	Enters rock at 10 feet.
Sec. 17, T. 27, R. 7 E	(?)	80	On a low gravel ridge.
Sec. 29, T. 27, R. 8 E	820	150	Enters rock at 6 feet.
Sec. 31, T. 27, R. 6 E	840	100	No rock entered.
Sec. 7, T. 26, R. 7 E	785	60	Enters rock a short distance.
Sec. 12, T. 26, R. 7 E	800	72	Enters rock at 20 feet.
Sec. 12, T. 26, R. 7 E	800	100	Enters rock at 98 feet; drift, gravelly.
NE. ¼ sec. 7, T. 26, R. 8 E	790	31	Enters rock at 10 feet.
Sec. 7, T. 26, R. 8 E	770	45	Enters rock at 35 feet.
Sec. 17, T. 26, R. 8 E	770	60	Enters rock at 9 feet.
Sec. 6, T. 26, R. 7 E	900	80	Enters rock at 15 feet.
Sec. 13, T. 26, R. 7 E	840	90	No rock entered; drift, mainly clay.
Sec. 14, T. 26, R. 7 E	850	100	No rock entered; over old valley of Yellow Creek.
Sec. 19, T. 26, R. 8 E	850	85	Entirely fine gravel and sand.
Sec. 30, T. 26, R. 8 E	850	90	No rock; drift mainly sand.
Sec. 5, T. 26, R. 8 E	785	104	Enters rock at 50 feet.
Sec. 8, T. 26, R. 8 E	775	110	Enters rock at 76 feet.
County Infirmary	775	161	Enters rock at 131 feet.
Sec. 13, T. 26, R. 7 E	800	100	Enters rock at 61 feet.
Sec. 12, T. 26, R. 7 E	850	192	Enters rock at 175 feet.
Sec. 14, T. 26, R. 7 E	850	248	Enters rock at 183 feet; drift, blue till.
Sec. 14, T. 26, R. 7 E	850	128	Enters rock at 115 feet; drift, variable.
Sec. 13, T. 26, R. 7 E	825	165	Enters rock at 141 feet; drift, variable.
Sec. 24, T. 26, R. 7 E	800	128	Enters rock at 112 feet; drift, variable.
Sec. 36, T. 26, R. 7 E	900	186	Enters rock at 140 feet; drift, variable.
Sec. 20, T. 26, R. 8 E	850	87	Enters rock at 70 feet; drift, variable.
Sec. 21, T. 26, R. 8 E	850	142	Enters rock at 120 feet; drift, mainly blue till.
Mr. Bolton, Bolton Station	819	70	Mainly blue clay; rock at bottom.
Sec. 31, T. 26, R. 7 E	900	70	Clay, 25 feet; remainder sand and gravel; rock at bottom.

WINNEBAGO COUNTY.

GENERAL STATEMENT.

Winnebago County is situated on the north border of the State midway between the Mississippi River and Lake Michigan, with Rockford as its county seat, and has an area of 552 square miles. The eastern portion of

the county is traversed from north to south by Rock River, the northwestern portion is traversed from west to east by the Pecatonica, and the southeastern portion from east to west by the Kishwaukee River.

The portion of the county west of Rock River has generally a thin coating of drift, except in the preglacial valleys. The majority of wells on the uplands enter rock at less than 20 feet. There are, however, occasional wells located probably over tributaries of the preglacial Rock or Pecatonica which penetrate 75 feet or more of drift without reaching the rock. Excellent exposures of the drift may be seen along the line of the Illinois Central Railway between Rockford and Freeport. Like the drift of Stephenson County, it is generally very stony and contains a considerable amount of gravel and sand. Much of this portion of the county is covered with a loess-like silt 4 or 5 feet in thickness, which furnishes an excellent soil.

The portion of the county east from Rock River carries a heavy deposit of drift, rock seldom being found at less than 100 feet, and it is probable that along the valley of Rock River and its immediate borders the thickness exceeds 300 feet, for borings to the north and south show that the rock floor of the preglacial valley stands 250 to 300 feet below the present stream bed. The drift of the eastern portion of the county embraces a sheet which extends but little west of Rock River and which, as indicated above, is referred to the Iowan stage of glaciation.

INDIVIDUAL WELLS.

A large number of well sections were collected by Mr. I. M. Buell during his investigation of the drumlins and bowlder distribution of Winnebago and Boone counties. But few records have been obtained by the writer. Mr. Buell has kindly turned over these well records for presentation in this report, and they appear in the table below. They are chiefly found in the district east of Rock River.

Table of well sections east of Rock River in Winnebago County, Illinois.

Owner or location.	Altitude.	Depth.	Remarks.
	Feet.	*Feet.*	
Sec. 14, T. 46, R. 2 E	900	60	Largely sandy drift; no rock.
	850	60	Drift till; strikes rock.
	900	65	Brow of bluff; no rock; gravel, 20 feet; blue clay, 35 feet.

Table of well sections east of Rock River in Winnebago County, Illinois—Continued.

Owner or location.	Altitude.	Depth.	Remarks.
	Feet.	*Feet.*	
Sec. 15, T. 46, R. 2 E	800	65	Till with gravel at bottom.
	750	30	Foot of bluff; drift till; no rock.
Sec. 1, T. 45, R. 2 E	925	107	Rock entered at 40 feet.
	900	120	Till, 65 feet; gravel, 16 feet; till, 10 feet; sand, 30 feet; no rock struck.
Sec. 2, T. 45, R. 2 E	900	75	Mainly till; upper part stony; rock at bottom.
	900	100	Bottom of well in gravel.
	900	110	Till, 75 feet; remainder sand.
Sec. 3, T. 45, R. 2 E	900	50	Rock at 50 feet or less.
	850	180	Rock struck at 65 feet.
Sec. 4, T. 45, R. 2 E	850	100	Brow of bluff; till, 80 feet; gravel, 20 feet; no rock.
	750	55	Foot of bluff; gravel (partly cemented), 46 feet; clay and sand, 9 feet; no rock.
	750	65	Rock river bottom; till, 43 feet; sand, 22 feet; no rock struck.
Sec. 15, T. 45, R. 2 E	850	55	In gravel at bottom.
	850	60	Rock struck at 57 feet.
	850	60	Gravel at bottom.
Sec. 22, T. 45, R. 2 E	825	35	Gravel at bottom.
Church N. of Argyle	900	50	In sand at bottom.
Sec. 32, T. 45, R. 2 E	825	45	Brow of bluff; gravel at bottom.
Sec. 5, T. 44, R. 2 E	800	28	Brow of bluff; ferruginous drift conglomerate.
Sec. 8, T. 44, R. 2 E	825	32	No rock; drift gravelly.
	825	90	Entirely till; no rock.
	825	50	Till; no rock.
	825	40	Till with cemented gravel at bottom.
	825	90	Sand at bottom.
Sec. 17, T. 44, R. 2 E	825	60	Dug through till; drilled through cemented gravel; loose gravel at bottom.
	825	140	Till, 100 feet; cemented gravel, 40 feet; no rock struck.
	825	140	Similar to preceding, and 40 rods distant.
Sec. 19, T. 44, R. 2 E	825	80	Till, 74 feet; gravel at bottom.
Sec. 20, T. 44, R. 2 E	825	50	No rock; mainly gravel.
	825	45	Similar to preceding.
Sec. 32, T. 44, R. 2 E	850	103	Wood in gravel below till at 75 feet; no rock struck.
	850	107	Till, 40 feet; sand at bottom.
	850	98	Sand at bottom.
	850	46	Rock struck at 45 feet.
Sec. 7, T. 44, R. 2 E	800	75	No rock struck; much ferruginous drift conglomerate in that vicinity.
Sec. 18, T. 43, R. 2 E	775	30	Drift, 30 to 40 feet in that vicinity.

Table of well sections east of Rock River in Winnebago County, Illinois—Continued.

Owner or location.	Altitude.	Depth.	Remarks.
	Feet.	*Feet.*	
Sec. 30, T. 43, R. 2 E	800	40	Mainly till; no rock.
Across road from preceding	800	40	Largely gravel; rock at bottom.
Sec. 34, T. 43, R. 2 E	775	95	No rock; mainly till. Hills at higher levels in that vicinity have thin drift.
James Hested, SE. part of county.	775	100	Drift, mainly till; rock struck.
Mr. Davis, SE. part of county	775	60	Drift ranges from 10 to 60 feet on the farm.
Mr. Watson, SE. part of county	800	90	No rock struck.
W. E. Corlett, S. of New Milford.	775	140	Bluff of Kishwaukee; no rock struck; quarries at a higher point toward the east.
Sec. 25, T. 43, R. 1 E	800	55	On gravel knoll; no rock.

The waterworks station at Rockford is located near the base of the west bluff of Rock River Valley in the north part of the city. Five wells are sunk to the Potsdam sandstone, from which water rises barely to the surface (719 feet above tide). With a diameter of 6 inches, each well furnishes about 200 gallons per minute by pumping. The drift ranges from 125 to 190 feet in depth. The upper portion is sand and gravel, but the lower portion is largely blue clay. No wells have been sunk in the midst of the valley at Rockford of sufficient depth to reach the rock. The distance to rock is probably much greater than in the wells at the waterworks.[1]

At Pecatonica wells usually obtain water in the limestone at depths of 80 to 125 feet. The drift in that vicinity is but a few feet in depth. The waterworks is supplied from springs.

In the vicinity of Winnebago Village the distance to rock ranges from 20 to at least 80 feet. Wells are usually obtained without entering rock, though several have been sunk some distance into the rock.

In the vicinity of Elida the drift is usually about 50 feet, and a few wells pass into the underlying limestone. West from Elida and also northwest, over an area of perhaps 50 square miles, wells usually obtain water in the rock at depths ranging from 40 to 100 feet. The drift in that locality is thin, seldom exceeding 20 feet. Mr. Buell, however, reports two wells in sec. 3, T. 26, R. 10 E., 50 and 60 feet in depth, which do not strike rock. Another well in the same section enters rock at 40 feet and is carried to a depth of 110 feet. Still another well located on a drift knoll enters rock at

[1] The data from Rockford have been furnished by Daniel W. Mead, C. E., of that city.

30 feet. In the neighboring section on the north there are several outcrops of limestone, though one well in that section fails to reach rock at 106 feet. A well in sec. 1, T. 26, R. 10, 114 feet in depth, enters rock at 50 feet.

In the northwestern one-fourth of the county rock is usually entered at slight depth except in a narrow belt along the Pecatonica and Sugar rivers. But here, as in the southwestern portion of the county, occasional wells on the upland reach a depth of 80 feet or more before entering rock.

BOONE COUNTY.

GENERAL STATEMENT.

Boone County is situated immediately east of Winnebago County, on the north border of the State, and has an area of but 290 square miles. Belvidere, the county seat, is situated near the southern edge of the county. It is drained chiefly by the Kishwaukee and its tributaries, which occupy gravel plains leading westward from the moraines of the Wisconsin drift sheet in McHenry County. These gravel plains are in places a mile or more in width and afford an abundance of water at shallow depth, wells seldom exceeding 25 feet.

The drift is thinnest in the southern portion of the county, there being numerous quarries in the two townships on its south border. In the northern part of the county the drift is probably not less than 75 feet in average depth, and it may possibly be as deep as in the neighboring portion of Winnebago County, from which the list of wells in the above table was prepared. Water is usually obtained at depths of 30 or 40 feet in that portion of the county from beds of gravel or sand associated with the till, the greater part of the drift being a typical till. In this county the glacial drift with its bowlders is not covered by deposits of loess or other silt as in counties to the west, and the surface sheet of drift, like that of eastern Winnebago County, is referred to the Iowan stage of glaciation.

INDIVIDUAL WELLS.

The city of Belvidere obtains its public water supply from a well sunk to a depth of 1,950 feet. The well is cased only to the limestone, 58 feet, and water is found at several horizons above the Potsdam (in which the well terminates) as well as in that formation. The head is but 6 feet below the well mouth, or 757 feet above tide. Though only 4 inches in diameter in its lower portion, it is found to have a capacity of 400 gallons per minute. The hardness of the water suggests that it is largely derived

from limestone. The private wells in this city usually obtain water from gravel at a depth of about 20 feet. A few in the south part of the city, outside the limits of the Kishwaukee gravel plain, are sunk to greater depth, but seldom exceeding 40 feet.

At the village of Caledonia, wells usually obtain water from beds of gravel beneath till at a depth of 30 or 40 feet. The following table of wells on farms in the neighborhood of Caledonia will serve to illustrate the variations in depth in the northern part of the county. It will be noted that only two of these wells enter the rock, viz, those in sec. 30, T. 46, R. 3 E., and sec. 7, T. 45, R. 3 E.

Depth of wells in northern Boone County.

	Feet.
John Van Anthrop, sec. 34, T. 46, R. 4 E	42
William Millard, sec. 35, T. 46, R. 4 E	34
William Smith, sec. 26, T. 46, R. 4 E	63
James Hineman, sec. 26, T. 46, R. 4 E	60
Sec. 30, T. 46, R. 3 E. (rock at 50 feet)	150
Sec. 7, T. 45, R. 3 E. (rock at 54 feet)	110
Sec. 4, T. 45, R. 3 E. (several wells)	30–40
D. S. Kelly, sec. 3, T. 45, R. 3 E	35
J. F. Ramsey, sec. 3, T. 45, R. 3 E	30
John Church, sec. 2, T. 45, R. 3 E	35
E. F. Bailey, sec. 1, T. 45, R. 3 E	21
Philip Coleman, sec. 6, T. 45, R. 4 E	24
Peter McIntyre, sec. 6, T. 45, R. 4 E	25
Peter Oleson, sec. 5, T. 45, R. 4 E	22
John Stall, sec. 4, T. 45, R. 4 E	76
J. Miller, sec. 3, T. 45, R. 4 E	63
Ole Nelson, sec. 3, T. 45, R. 4 E	65
T. L. Bowman, sec. 3, T. 45, R. 4 E	48
Herbert Young, sec. 3, T. 45, R. 4 E	35

In Bonus Township, situated northeast from Belvidere, the wells on the upland between the Kishwaukee River and Piscasaw Creek in several instances reach a depth of about 60 feet without entering rock.

Although rock is usually struck at comparatively slight depth in the southeast township (T. 43, R. 4 E.), a well at a cheese factory in sec. 15 did not reach rock at a depth of 83 feet. Several wells in secs. 8, 9, 16, and 17 of this township enter rock at depths ranging from 4 feet to 20 feet on an upland standing about 900 feet above tide. On Coon Creek gravel plain, in sec. 3 of this township, at an elevation less than 800 feet above tide, a well 45 feet in depth does not reach rock. A well at Mr. Ryan's, in sec. 33, at an elevation about 775 feet above tide, is 86 feet in depth and strikes rock at 33 feet. Wells in sec. 23 reach a depth of 30 or 40 feet without entering rock.

In the southwest township of the county, in the vicinity of Irene, wells are usually sunk into the rock, though the drift in places exceeds 30 feet. The Illinois Central Railway cutting, immediately west of Irene, shows an extensive exposure of black soil containing molluscan shells underneath a sheet of till. The soil appears to separate the Iowan till sheet from the Illinoian in which case it is referable to the Sangamon interglacial stage.

McHENRY COUNTY.

GENERAL STATEMENT.

McHenry County is situated immediately east of Boone, on the north border of the State, Woodstock being its county seat, and has an area of 624 square miles. Its western portion is drained by the Kishwaukee and tributaries westward to Rock River, while the eastern portion is drained southward through Fox River, which has its course near the eastern border of the county through a series of lakes and sloughs. This is one of the most elevated counties in the State, several square miles on its northern border being above the 1,000-foot contour, while much of the county stands above 900 feet.

The greater part of the county is occupied by a system of moraines formed at the Wisconsin stage of glaciation, there being only a narrow strip on the western border of the county, scarcely a township in average width, which lies outside its outer morainic system. This is underlaid largely by a gravel overwash from the moraine, and is therefore of Wisconsin age. There are a few outcrops of rock near the Kishwaukee in the western portion of the county at an altitude about 800 feet above tide, but these appear to stand above the general level of the rock surface and represent probably the tops of preglacial ridges or hills. Several deep wells scattered widely over the county have shown the presence of a very thick deposit of drift. It is probable that the average depth is not less than 200 feet, or nearly twice the average depth of drift for the State.

The wells for household use usually obtain water at moderate depth (20 or 30 feet), but wells for stock are often sunk to depths of 100 or even 200 feet. Dairying being one of the principal industries of the county, a large number of farmers have sunk deep wells to supply their cattle. The records of only a few of these were obtained, but they are thought to be representative.

INDIVIDUAL WELLS.

The northwestern township of the county (Chemung) is occupied chiefly by a gravel plain, in which wells are obtained at a depth of 25 to 35 feet. In the vicinity of Chemung, however, the wells encounter till, and their depth ranges from 20 feet to 70 or more, water being obtained in beds of gravel associated with the till.

The railway well at Harvard, in the southeast part of Chemung Township, is sunk to a depth of 900 feet, and is thought to terminate in the lower portion of the St. Peter sandstone. The following strata were penetrated:

Section of the railway well at Harvard, Illinois.

	Feet.
Yellow and blue till	36
Gravel and bowlders	24
Sand and loose gravel	15
Coarse gravel	15
"Hardpan"	12
Limestone	108
Shale	85
Mainly limestone	345
Mainly sandstone	240

The water is hard and is apparently largely derived from the limestone. It rises within 41 feet of the surface, or to an altitude 894 feet above tide. The well is cased only to the rock (102 feet), and has a diameter of 7 inches below the casing. The capacity is estimated at 90 gallons per minute. Many private wells are obtained in Harvard at a depth of about 25 feet. The west part of the village is on a gravel plain, with a sheet of water at 20 to 25 feet or less. The railway station and east part of the village stand on the slope of a moraine.

In the township east of Chemung only one well record was obtained—that at the cheese factory in the village of Alden. This well reached a depth of 150 feet without entering rock, and has the following section:

Section of well at a cheese factory in Alden, Illinois.

	Feet.
Gravel and sand	15
Blue till	100
Black soil	2
Till of bluish color	33

It is probable that the soil struck at the base of the blue till marks either the junction between the Wisconsin drift sheet and the Iowan, or between the Iowan and Illinoian. The well is on a moraine.

In the vicinity of English Prairie post-office, in the northeast part of the county, there is an extensive gravel plain standing at an elevation slightly above 800 feet, in which occasional wells have been sunk to a depth of 150 feet without reaching rock, mainly through gravel.

At Woodstock, the county seat, a boring was made some years ago which struck a black soil at about 160 feet, beneath which was till, in which the well terminated at a depth of 180 feet. This soil, like that at Alden, probably marks the junction between the Wisconsin and Iowan drift sheet, or possibly between the Iowan and Illinoian. A well has been sunk in Woodstock to a depth of 1,014 feet, but no accurate record of the strata penetrated appears to have been kept. The drift has a thickness of 230 feet. The well is said to terminate in sandstone, probably St. Peter. A water-bearing "sand rock" was entered at 825 feet. The water is reported to be soft and of a pleasant taste, and has a capacity of 150 gallons per minute from a pipe $6\frac{1}{2}$ inches in diameter. The head is 60 feet below the surface. Many private wells in Woodstock and vicinity obtain water at depths ranging from 20 to 60 feet. They are mainly through till, though beds of sand and gravel occur.

At Marengo the wells vary greatly in depth, those on the gravel plain along the Kishwaukee being but 20 to 25 feet, while those on the slope of the moraine in the south part of the city are often 60 to 80 feet, and occasionally 125 feet or more. So far as ascertained, no wells reach the rock. The drift is largely of gravelly constitution. A well belonging to Mr. P. T. Parkhurst, 100 feet in depth, penetrated a black muck at about 60 feet, from which inflammable gas issued. This muck probably underlies the Wisconsin drift sheet. A similar muck was struck on the farm of James Smith, 3 miles northwest of Marengo, at a depth of only 28 to 30 feet. The well stands on the slope of the outer moraine of the Wisconsin drift, slightly above the level of the older sheet of drift to the west. The soil in all probability is at the base of the Wisconsin drift and above the Iowan drift. At a cheese factory south of Marengo, in sec. 11, T. 43, R. 5 E., a well struck a black muck beneath blue till at a depth of 70 feet. As the well is situated on the moraine at about 70 feet above the Iowan drift plain to the west, the soil probably caps Iowan drift.

At the village of Crystal Lake wells usually obtain water at depths of 50 to 70 feet and are largely through gravel. A well about 4 miles southwest of this village, in sec. 12, T. 43, R. 7 E., reached a depth of 210 feet

without entering rock. Water is obtained in gravel near the bottom, the greater part of the well section being till.

In the vicinity of Cary wells are 60 to 100 feet in depth. They usually penetrate about 50 feet of dry gravel, beneath which is till, having water-bearing beds associated with it.

At Algonquin, in the southeast corner of the county, an artesian well was sunk to a depth of 2,527 feet by the Illinois Condensing Company. Rock is struck at about 100 feet, and the well probably terminates in Potsdam sandstone. At last reports the use of the well had been discontinued because of the corrosion of the pipes by the water. The public water supply for this village is from springs. Many wells on the low ground obtain water at about 12 feet. A few have been bored to depths of 60 or 80 feet. They enter till after penetrating 12 to 20 feet of gravel. Occasional flowing wells are obtained in this vicinity. One in the valley of Crystal Lake outlet, about a half mile above Algonquin, has a depth of 60 feet. One at a blacksmith shop in the north part of Algonquin is 62 feet in depth, and has a head 14 feet above the surface. The bordering uplands rise to a height of about 100 feet above the level of the wells, and thus furnish an absorbing area of sufficient height to give a strong hydrostatic pressure.

At South Riley, in the southwest part of the county, rock is usually entered below blue till at a depth of about 60 feet, or at an elevation not far from 800 feet above tide. Rock is also struck in several wells on the plain northwest from Marengo, in the southwest part of T. 45, R. 5 E., and northwest part of T. 44, R. 5 E., at a depth of about 60 feet. The general elevation of the region is about 850 feet above tide. A short distance east from these wells, however, a well on the farm of Mr. Alsing, sec. 35, T. 45, R. 5 E., reached a depth of 100 feet without entering rock.

The following sections of farm wells are of interest because of their depth. They are located on or among the moraines of the Wisconsin drift sheet and none of them reach the rock:

Deep drift borings in southeastern McHenry County.

	Feet.
Moses Dimon, 2 miles south of Marengo	125
R. Cooney, sec. 14, T. 45, R. 6 E	94
Harmony post-office	112
Ira Curtiss, near center of T. 43, R. 6 E	180
Well 80 rods east of preceding	86
W. Whittemore, T. 43, R. 7 E	100
Mr. Cummings, near Huntley	108
George Bunker, T. 44, R. 7 E	84

The well at Mr. Cummings's overflows, although at an altitude about 900 feet above tide, and that at Mr. Whittemore's rises nearly to the surface. The absorbing area is probably on a moraine south of the wells, which rises to a higher elevation than that of the well sites. All the wells in the above list are mainly through till. In this connection it may be remarked that the moraines of this county appear to be composed chiefly of till, the principal exception being a gravelly area occupying a few square miles in the vicinity of Crystal Lake and thence eastward to Fox River.

LAKE COUNTY.

GENERAL STATEMENT.

Lake County is situated in the extreme northeast corner of the State, on the border of Lake Michigan. It has an area of 490 square miles, and the county seat is Waukegan. The eastern portion of the county is traversed from north to south by the Des Plaines River, while the western portion is touched by Fox River. There are numerous lakes in the western half of the county, situated among the knolls and ridges of the Valparaiso morainic system. There are also extensive marshes and sloughs bordering these lakes and Fox River. The Valparaiso morainic system, which occupies much of the western half of the county, stands 200 to 300 feet above Lake Michigan. Other moraines, occupying a narrow belt between the Des Plaines and Lake Michigan, stand 100 feet or more above the lake.

The drift of this county probably has an average thickness of more than 200 feet. The few wells which enter rock find a rock surface lower than the level of Lake Michigan, and several other deep borings penetrate below the level of Lake Michigan without entering rock. It is scarcely probable that the rock surface will average an elevation as great as the level of the lake (580 feet above tide). The upper portion of the drift, to a depth of about 150 feet, is chiefly a soft blue till, thought to be of Wisconsin age. Beneath this occasional borings in Lake, as in neighboring counties on the south and west, enter a hard till, thought to belong to the earlier stages of glaciation.

The wells in this county usually obtain water at moderate depths, from gravel or sand associated with the till. Such wells, however, are often weak, and farmers have occasionally sunk to depths of 200 feet or more in order to obtain a larger supply.

INDIVIDUAL WELLS.

At Waukegan the public water supply was formerly obtained from artesian wells, but since 1895 it has been obtained by pumping from Lake Michigan. Three wells were sunk to depths of 1,135, 1,600, and 2,005 feet, respectively. The first well is reported by Mayor De Wolf to have obtained water of fair quality, though rather heavily charged with iron. The second well obtained an unpleasant water with bad odor, thought to be sulphurous. The wells were discontinued because of the hardness of the water, it being unfit for boiler use. The water also was found unsuitable for sprinkling lawns, it being destructive to grass. The Lake Michigan water is not too hard for boiler use and in other ways is more satisfactory than the artesian water. The present intake is at a distance of 1,700 feet from the shore, but it is proposed to extend the tunnel to a distance of about a mile.

At Lake Forest, wells which will yield 30 barrels per day are usually obtained at a depth of 40 feet or less. An artesian well at the residence of Hon. C. B. Farwell reached a depth of 960 feet and obtained a flow of water whose head was originally 50 feet above the surface, or about 125 feet above Lake Michigan. The drift at this well has a thickness of 160 feet.

At Highland Park there are four artesian wells with depths of 1,800 to 2,200 feet. Mr. P. T. Dooley, a well driller, residing at this village, reports that wells 5 inches in diameter yield about 150 gallons per minute. A strong flow of water is obtained at about 900 feet and also at about 1,300 feet, as well as at lower horizons. The wells all flowed when first made, but at present scarcely reach the surface. The elevation of the well mouths is 110 to 115 feet above Lake Michigan, or 690 to 695 feet above the sea. The thickness of the drift is about 175 feet.

At Milburn, in the north part of the county, on a plain between the Valparaiso moraine and Des Plaines River, several flowing wells have been obtained, and the wells on this plain usually show marked hydrostatic pressure. In some cases they are but 20 feet in depth, and rarely exceed 75 feet.

Near Wauconda, in the western part of the county, several wells reach a depth of 70 or 80 feet, though shallower wells are common.

Near Lake Zurich, in the southwestern part of the county, a few wells have been sunk to depths of over 200 feet without entering rock. One in the village of Lake Zurich reached a depth of 240 feet; one on the Fletcher farm in sec. 32, a depth of 230 feet, and one about a mile east of the village reached a depth of 297 feet. The latter has the following section:

Section of well near Lake Zurich, Illinois.

	Feet.
Yellow till	12
Blue till	88
Fine sand	197
Total	297

Gravel at bottom.

A well driller states that much sand is found at depths of 100 feet or more beneath the crest of the Valparaiso moraine in the vicinity of Lake Zurich.

At Barrington, on the south line of the county, two wells enter rock at 254 and 258 feet, respectively. They encounter considerable coarse gravel and cobble at about 160 feet. The remainder of the section is mainly till. It is thought that this cobble bed occupies the junction between the Wisconsin and earlier sheets of drift, there being a change to a harder till beneath it.

At Hainesville, in the north central part of the county, good wells are usually obtained at 80 or 90 feet, but one boring is reported to have reached a depth of 287 feet without obtaining water or entering rock. Another unsuccessful boring is reported to have been made at Gilmer, in the south central part of the county. It reached a depth of 213 feet without entering rock. At Deans Corners rock was struck at 290 feet. At Ravinia, in the southeast corner of the county, a well 186 feet in depth entered rock at 164 feet.

COOK COUNTY.

GENERAL STATEMENT.

Cook County, of which Chicago is the county seat, has a wide frontage on Lake Michigan and extends back to distances of 15 to 30 miles from the lake, there being much irregularity in the western border. It is one of the largest counties of the State, the area being 960 square miles. The Chicago River, whose main branch heads near the north line, flows southward near the eastern edge of the county and enters the lake through the

midst of the city of Chicago. Calumet River enters the county from Indiana, and after running westward to Blue Island, a distance of about 12 miles, it turns abruptly eastward. As previously noted, it formerly returned into Indiana and discharged at the head of the lake, but the present mouth of the river is at South Chicago, in Illinois. The Des Plaines River flows southward from the north line of the county to Summit, having an average distance of about 10 miles from the lake. It there turns southwestward, leaving the county near the village of Lemont. The extreme northwestern portion of the county is tributary to Fox River. Drainage lines are poorly developed in both the elevated and the low-lying portions of the county, a feature which is characteristic of several counties in northeastern Illinois.

The eastern portion of the county is a plain rising gradually westward to the borders of the Valparaiso morainic system. A large part of this plain stands only 10 or 15 feet above Lake Michigan, but on the western border its elevation is 40 to 60 feet or more. The plain is interrupted by a small drift ridge leading north a few miles from Blue Island. There are also drift ridges near the border of Lake Michigan, in the north part of the county, which rise to a height of 75 or 100 feet above the lake. The portion of the plain standing within 60 feet of lake level, as already noted, has been occupied by Lake Chicago, whose discharge was southwestward through the "Chicago Outlet."

The Valparaiso morainic system passes across the northwestern part of Cook County in a southward course, and, after crossing Dupage County, again enters Cook, occupying the southwestern borders of the county. This system stands in its higher parts fully 200 feet above the lake, and a small area in the extreme northwest part of the county reaches an elevation more than 300 feet above the lake.

The drift is comparatively thin on much of the plain in Chicago and to the south and also along the Chicago Outlet, rock quarries being numerous and many instances of wells encountering rock at slight depth being found. There are, however, occasional wells which reach a level 100 feet or more below Lake Michigan before encountering rock. The available data seem to indicate that a buried valley enters the lake near Lincoln Park, whose course can be followed for several miles back from the lake

in a westward direction. Wells along this valley reach a level 115 to 125 feet below the lake before encountering rock.[1]

In the northern part of the county the rock surface appears to be generally lower than in the southern, though the drift surface is higher. The thickness of drift is found to be in places 250 or even 300 feet, while the average probably exceeds 200 feet. Well sections reaching the rock have been obtained in all parts of the county at frequent intervals, except in the portion occupied by the Valparaiso moraine on the southwest border, or in about 800 square miles of the 960 embraced in the county. Sixty-two wells are found to show an average of 83 feet to rock, while 47 fail to enter rock at an average depth of 79 feet. The drift is largely a compact till, except in the northwest part of the county, where thick deposits of sand and gravel are frequently found beneath a sheet of blue till. Beds of sand or gravel are, however, associated with the till in sufficient amount to furnish a fair supply of water for wells. In a few instances wells in the northwest part of the county have penetrated a black soil below till at depths in some cases of over 100 feet. It is thought that the drift above such soils should be referred chiefly to the Wisconsin stage of glaciation. The soil may, however, in some instances be found below the Iowan drift.

INDIVIDUAL WELLS.

In the city of Chicago several sources have been drawn upon for wells, but the public water supply is pumped from Lake Michigan. Since the drift is generally thin, there are only small areas where wells or rather where pure water may be obtained above the rock. The north part of the city, however, obtained water from the drift in the early days of settlement. The danger of contamination of such wells by sewage or otherwise is so great that their use is largely discontinued.

The Lockport (Niagara) limestone, which underlies the city, has been drawn upon for water from the early days of settlement, but the use of water from this source is decreasing, in part because of danger from contamination, and in part because of a sulphurous odor which often characterizes the water.

Artesian wells have come into extensive use within the past thirty

[1] The position of this valley was noted first by Mr. Samuel Artingstall about 1886, while city engineer of Chicago.

years. The first well was sunk in 1864 in the northwest part of the city, on the highest ground then within the city limits, and at an altitude of 31 feet above Lake Michigan, the precise location being at the corner of Chicago and Western avenues. This well was sunk by a band of Spiritualists with a view to prospecting for petroleum, and it is reported that the site of the well was determined by Mr. James, a so-called medium, while entranced. Only a small amount of oil was found, but at a depth of 711 feet a strong flow of water was struck, which rose to a height of 80 feet above the surface, or 111 feet above Lake Michigan. A second well only a few feet distant was sunk the following year, which obtained a flow of water at a depth of 694 feet. The history of these wells is set forth in an interesting manner in a pamphlet entitled "History of the Chicago artesian well," by George A. Shufeldt, jr., issued by the Religio-Philosophical Publishing Association of Chicago in 1867. Mr. W. T. B. Read, who drilled the wells, still resides in the city.[1] He reports that the head has decreased to such an amount that the water now stands 15 or 20 feet below the surface, or nearly 100 feet below its original head, and that the wells are not in use. These wells apparently obtained their supply of water from the Galena limestone, the depth being insufficient to touch the St. Peter sandstone.

Within a few years after the drilling of the wells just noted, several deeper ones were sunk in the city and strong flows were obtained. The earlier ones usually reached the St. Peter sandstone, but it is probable that much of their supply came from higher strata. At the present time there are several hundred wells within the city used by the various industries which demand large quantities of water. A large part of them penetrate only to the St. Peter sandstone, but many enter the underlying limestone and not a few reach the Potsdam sandstone. The deepest ones are about 2,700 feet. At this depth water is much more saline than in the St. Peter sandstone or Galena limestone. The disadvantage resulting from salinity will probably restrict the boring of wells in the future to depths of not more than 2,500 feet. The boring of so many wells within a limited area has led to such an excessive drain upon the rock strata that the head is kept below the normal, and an overflow is now rarely obtained.

The deepest drift encountered in Cook County, so far as known to the writer, is in a well at Samuel Church's, near the center of the northwest

[1] At 950 West Chicago avenue.

township (sec. 22, T. 42, R. 9 E.). This boring reached a depth of 315 feet without encountering rock or obtaining water. As the altitude there is about 825 feet, the boring reached a level only 70 feet below that of Lake Michigan. Another boring 5 rods distant obtained a strong well from glacial gravel at a depth of 170 feet. Between this well and the city of Elgin several wells are found to enter rock at depths of 220 to 240 feet.

Two wells east of Elgin are reported to have passed through an old soil beneath the till. In one well the soil occurs at the base of the drift at a depth of 67 to 70 feet. In the other it occurs at about 165 feet, while the rock is entered at 192 feet. The wells in that vicinity penetrate a bluish till, but on the borders of Fox River a brown or reddish till is reported to extend to considerable depth.

A well one-half mile west of Spaulding Station, 137 feet in depth, enters rock at 120 feet. The drift is mainly blue till.

At Bartlett several wells reach a depth of 90 or 100 feet, mainly through till. At Ontarioville the wells of greatest strength are found at depths of 60 feet or more, and occasionally reach 140 feet without entering rock.

In Palatine Township a large number of deep wells have been sunk, partly because of the difficulty in obtaining water at shallow depths and partly for the purpose of obtaining an overflow. At the time of the writer's visit to that township, in 1887, there were not less than 25 flowing wells. They are located principally in the central portion, near the village of Palatine, but occasional flows are obtained in other parts of the township as well as in neighboring townships. In the southwest part the altitude is too great for a flow, but several wells have been sunk there to depths of 150 to 180 feet without reaching rock. The following wells in the village of Palatine serve to show the differences in depth of the wells and the relation to rock strata:

Flowing wells at Palatine, Illinois.

	Feet.
Palatine town well, enters rock at 152 feet	160
Palatine railroad well, crust of rock at bottom	165
Palatine deep artesian well, enters rock at 147 feet	1,656
Palatine Flax Mill, does not reach rock	170
One block north of Flax Mill, not to rock	70
Palatine Cheese Factory, crust of rock at bottom	163

The well at the cheese factory, when first made, would rise into the second story, and that at the flax mill to a level 10 feet above the surface.

The other wells show a rise scarcely so high, though their mouths are at an equally low elevation. The well 70 feet in depth has a strong flow of chalybeate water. The strongest flow is from the cheese factory well—60 gallons per minute. The crust of rock reported in these wells is perhaps a ferruginous incrustation of gravelly drift, such as is often formed above water beds in the drift. In the deep artesian well a strong flow of water is reported from a depth of 800 feet as well as from near the base of the drift. The collecting area for the shallow wells is thought to be in the portion of the Valparaiso moraine west and north of Palatine, which attains an altitude of 100 to 120 feet above the station. The superficial drainage is very poor along this moraine, and much of the water must evaporate or find outlet by underground passages. The collecting area seems adequate for supplying the flowing well district. The following section of a well at the flax mill will illustrate the character of the deposits penetrated in each of the wells:

Section of well at Flax Mill, in Palatine, Illinois.

	Feet.
Yellow till	10–12
Blue till	25–30
Water-bearing gravel	3–4
Blue till, with occasional thin beds of sand and gravel, yielding water	125

The lower portion of the till is said to be more sandy than the upper. In the north part of Palatine Township there are several wells ranging in depth from 80 to 165 feet, which show strong hydrostatic pressure. On the lowest ground they occasionally rise within 5 or 10 feet of the top, and in two or more instances they overflow.

In the township adjoining Palatine on the south (T. 41, R. 10 E.) flowing wells have been obtained along a tributary of Salt Creek in sections 23, 25, and 26, at depths of 27 to 45 feet. Being so shallow they differ but little from springs which occur in that vicinity. A few deep wells have been made in the western part of this township. The following section is from one in its northwest corner, at an altitude about 825 feet:

Section of a well in northwest part of T. 41, R. 10 E.

	Feet.
Yellow till	10–15
Blue till	125
Black soil	4
Sandy till	50
Gravel with water	2
Total depth	195

At Arlington Heights a well drilled to a depth of 800 feet penetrates 128 feet of drift. No further data concerning the well were obtained. A well in this village penetrated a black soil beneath blue till at a depth of 70 to 75 feet, beneath which it entered another sheet of till. A well 2½ miles north of Arlington Heights entered rock at a depth of 195 feet.

At Des Plaines Village, which is situated on a gravelly plain, wells penetrate about 12 feet of gravel before entering till. Some obtain their supply in this gravel, others from gravel associated with the till. The depth seldom exceeds 30 feet. The public supply is from an 8-inch well 200 feet in depth.[1]

A well on the farm of John Back, near Schermerville, 162 feet in depth, enters rock at 147 feet. In the village of Schermerville wells are often 60 feet, and in some instances over 100 feet in depth, and obtain water from gravel beneath the till.

At the village of Oak Glen several flowing wells have obtained water either near the base of the drift or in the upper part of the underlying limestone at depths of 90 to 120 feet. Mr. F. N. Hoffman's well, 118 feet in depth, struck one water vein in gravel at 78 to 80 feet and another at the top of the limestone at 114 to 118 feet. Water in this well rises 4 feet above the surface. A well near Oak Glen, in sec. 25, 160 feet in depth, does not reach rock, though its mouth is scarcely 60 feet above Lake Michigan.

At Park Ridge, at an altitude 660 feet above tide, an artesian well enters rock at 103 feet. The drift is mainly till. No further data were obtained. A well about 3 miles north of Park Ridge at slightly higher altitude enters rock at 110 feet.

At Winnetka, at the residence of Mr. Lloyd, a well 1,570 feet in depth enters rock at 150 feet. The water rises to a level nearly 40 feet above Lake Michigan. Wells are obtained in this village at depths of 20 to 50 feet in beds of gravel associated with the till.

At Wilmette rock is entered at about 140 feet, or nearly 100 feet below the level of Lake Michigan. A deep well has a head about 20 feet above the lake level. No further data were obtained.

An artesian well at Evanston, 1,602 feet in depth, enters rock at 72 feet, or about 42 feet below the level of Lake Michigan. Water rises to a

[1] Manual of American Waterworks, 1897.

height 34 feet above lake level, or 614 feet above tide. The well reaches the Potsdam sandstone. An analysis of the water is presented in the Seventeenth Annual Report of this Survey.[1] The temperature of the water is 61.7 degrees Fahr. Many wells are obtained in this city at a depth of 35 feet or less near the bottom of the beach sand. The peaty deposits which occur at that horizon in some cases give the water an unpleasant odor. The use of private wells is decreasing, being supplanted by the public supply which is pumped from Lake Michigan.

In the vicinity of Niles Center several wells strike rock at depths ranging from 85 to over 100 feet. The gravel and sand of the lake beach is 8 to 12 feet in depth. The underlying glacial drift is mainly till.

At Morton a well 115 feet in depth enters rock at about 100 feet. The drift is mainly blue till.

In Bowmanville and vicinity several wells near the Chicago River reach a depth of 80 feet without striking rock. In some instances they penetrate about 20 feet of beach gravel. A well at Rose Hill Cemetery, near Bowmanville, strikes rock at 100 feet. The upper 30 feet is gravel and sand, beneath which is a compact till extending to the rock.

In several suburbs in the northwest part of Chicago rock is struck in artesian wells at 60 to 100 feet, as follows:

Drift in artesian wells in northwest part of Chicago.

	Feet.
Jefferson Park	68
Irving Park	79
Montrose	60
Norwood Park	90
Near County Infirmary	71
Same locality	101
Oak Park	65, 85, and 45
Near Cragin	20

In all of these wells the greater part of the drift is blue till. The beach gravel and sand seldom amount to more than 5 or 10 feet.

A well at River Park, near the Des Plaines River, 115 feet in depth, enters rock at 100 feet. A well at Turner Park obtains water from sand below till and just above the rock at a depth of 80 feet. Mr. Koch, near Dunning, has a well 114 feet in depth which did not reach rock. Wells in the vicinity of Galewood, 60 feet in depth, are mainly through till and do not reach rock. Wells at Maywood, 40 feet in depth, do not reach rock,

[1] Part II, p. 827.

but within 2 miles west of Maywood rock is struck at about 30 feet. The Manual of American Waterworks (1897) reports that the public supply is from an artesian well. A well in the Des Plaines valley near the Twelfth street bridge does not reach rock.

At Riverside the water supply is obtained from artesian wells about 2,200 feet in depth, which reach the Potsdam sandstone. The supply is partly from the St. Peter and other strata above the Potsdam. The wells originally overflowed, but the head is now 20 feet below the surface, or about 600 feet above tide. With a diameter of but 3½ inches, the capacity of one of these wells is estimated to be more than one million gallons per day.

At Lagrange the public supply is from artesian wells, but no data were obtained concerning their depths and capacities. In the east part of the village a flowing well is obtained from the drift at a depth of 21 feet. Rock outcrops within the limit of this village at a higher elevation than the mouth of this well. On the plain east of Lagrange rock is frequently struck at about 20 feet. The drift there is mainly a blue clay, there being only 5 or 6 feet of yellow clay at surface. In some cases sand and gravel occur just above the rock. West of Lagrange, in the vicinity of Western Springs, wells often reach a depth of 40 or 50 feet without entering rock.

Borings in the vicinity of Summit show the depth to rock to range from 10 feet or less to fully 40 feet. The beach gravel in the south part of the village is shown by a gravel pit to have a depth of 20 feet. Beneath this gravel is blue till. On the plain southeast from Summit several wells are sunk 45 to 55 feet without reaching rock.

At Washington Heights a well at Klein's Hotel enters rock at 70 feet, penetrating the following beds:

Section of well at a hotel in Washington Heights.

	Feet.
Gravel	3
Yellow till	5
Blue till	63
Limestone	3

Other wells are obtained in that vicinity at shallower depths. The public water supply is from a deep well.[1]

A well at Morgan Park, on the crest of the Blue Island till ridge, 1,046 feet in depth, has a head 594 feet above tide. Limestone is entered at a

[1] Manual of American Waterworks.

depth of 163 feet, or about 100 feet below the level of Lake Michigan. The well record indicates a soft till extending from the surface to a depth of 86 feet, beneath which there is a harder material called shale, but perhaps a till, 77 feet in depth. Another well in Morgan Park is reported to have struck limestone at a depth of only 90 feet.

At Riverdale rock is entered at about 45 feet, at Dolton at 35 or 40 feet, and in the vicinity of Harvey at 20 or 25 feet. The public water supply at Harvey is obtained from deep wells, one of which derives its water from the St. Peter at 1,300 feet and another terminates in Potsdam at 2,075 feet.

At Blue Island wells usually reach water in sand, connected with the lake occupancy, at a depth of about 25 feet.

On "Lanes Island," in the Sag outlet, several wells reach a depth of 30 feet without entering rock. After penetrating 4 to 8 feet of sand they are mainly through till.

At the village of Worth wells usually obtain water at about 16 feet in sand below till. Rock is exposed along the Sag outlet in that vicinity at about the level of Lake Michigan. A well 4 miles east of Worth, in sec. 23, T. 27, R. 13 E., reaches rock at 55 feet. The drift is mainly till.

On the island-like tract of moraine between the Sag outlet and Des Plaines, northwest of Worth, several wells reach a depth of about 80 feet without entering rock. They are mainly through blue till.

On the Valparaiso moraine, in the south part of Cook County near Alpine, several wells have a depth of 80 feet without entering rock. Small amounts of inflammable gas have been found in some of these wells.

In the vicinity of Matteson and northward in T. 35, R. 13 E., wells frequently reach depths of 50 to 65 feet without entering rock. In the vicinity of New Bremen, in T. 36, R. 13 E., the wells are frequently 75 feet in depth and obtain water in gravel beneath the till.

In the vicinity of Glenwood wells along the beach penetrate 8 to 12 feet of gravel before entering till, and strike rock at about 30 or 35 feet.

A flowing well was obtained by Mr. Winterhoffe on his farm in sec. 6, T. 35, R. 15 E., at a depth of 75 feet without reaching rock. It was through till the entire depth. A neighboring well at Lewis Peter's enters rock at 85 feet, but the water level is 14 feet below the surface. Another well, in sec. 12, T. 35, R. 14 E., strikes rock at 85 feet and there obtains water, which

rises within 2 feet of the surface. Still another well, in sec. 7, T. 35, R. 15 E., only 60 feet in depth, encountered rock at the bottom, which may possibly have been a bowlder.

The public water supply for Chicago Heights is obtained from four wells about 200 feet in depth located on the plain north of the village. The head is not sufficient to cause an overflow. The drift in the vicinity of this village is but 20 or 30 feet in depth and some of the private wells enter the rock; occasionally they are sunk to a depth of 80 or 90 feet. In the district east of Chicago Heights, as far as the State line, wells are usually obtained at a depth of about 35 feet, from gravel below till.

DUPAGE COUNTY.

GENERAL STATEMENT.

Dupage County is situated west of the middle portion of Cook County, and has an area of but 340 square miles. Wheaton, the county seat, is situated near its geographic center. Its drainage is southward, the eastern border being tributary to Salt Creek and the middle and western portions to the East and West Dupage rivers, respectively. Like the portion of Cook County on the north, it is poorly drained, although standing much above the bordering plain on the east. The eastern two-thirds of the county is occupied by the Valparaiso moraine, which carries numerous sloughs and basins among its knolls and ridges. It affords excellent pasture lands and is extensively used in dairying, the leading pursuit of the county.

On the dairy farms wells are frequently sunk to depths of 100 feet or more. The thickest drift section obtained is 162 feet, and 20 wells which reach rock show an average depth of 86 feet, while 17 of the deep wells which fail to reach rock show an average depth of 94 feet. From these sections, which are distributed widely over the county, the thickness of the drift may be inferred to average not less than 100 feet. The drift is thinnest in the southwestern portion, on the borders of the West Dupage River, where numerous quarries of limestone have been opened. Rock also comes to the surface near Elmhurst, in the southeast part. The drift in this county, as in northwestern Cook County, consists mainly of a blue till, but beds of sand and gravel are associated with the till at various levels and supply the water for wells.

INDIVIDUAL WELLS.

In the northwestern township of the county, sections of three deep wells were obtained near Wayne, one of which in sec. 7, 105 feet, and one in sec. 8, 150 feet, in depth, do not reach rock, but one in sec. 33 enters rock at 162 feet. In the first two wells a large amount of sandy material was penetrated, but the third well penetrated nothing but till.

In the middle township of the north tier several wells have been sunk near Roselle to a depth of 100 feet or more without entering rock. The majority of them are mainly through till.

In the northeast township several flowing wells have been obtained in the vicinity of Itasca at shallow depths along a tributary of Salt Creek. The depths are but 20 to 30 feet, and the water rises scarcely 5 feet above the surface. There are also numerous shallow flowing wells along Salt Creek between Salt Creek Station and Elmhurst. It should be noted that this flowing-well district is adjacent to that of Cook County, discussed above. The altitude is 75 feet or more lower than at Palatine, being scarcely more than 650 feet along Salt Creek Valley, and about 690 feet at Itasca. Neighboring portions of the Valparaiso morainic system on the west rise fully 100 feet above the wells at Itasca, and it is probable that this moraine constitutes the absorbing area.

A well at Bensonville, about 2,000 feet in depth, penetrates 97 feet of drift. No further data concerning the well were obtained.

At Elmhurst records were obtained of two wells which strike rock at 70 and 98 feet respectively. Within a mile west of these wells a limestone quarry is opened at a level only 15 or 20 feet below the well mouths. About 3 miles south also a quarry is opened on the bluff of Salt Creek. The public water supply is pumped from a spring about 3 miles distant from the town.[1]

Along the valley of Salt Creek, south from Elmhurst, wells are in places sunk to a depth of 50 feet, mainly through gravel. At the village of Fullersburg, however, wells obtain their supply of water in gravel at a depth of but 12 feet.

At Hinsdale the public water supply is obtained from a well 864 feet in depth. This is reported by the Manual of American Waterworks to afford 1,000,000 gallons per day. The last edition of this manual reports a

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[1] Manual of American Waterworks, 1897.

second deep well in use. The drift in the vicinity of Hinsdale is about 100 feet in depth and is mainly till. On the moraine west and northwest from this village several wells show the drift to be over 150 feet in thickness. One at a brickyard, in sec. 10, T. 38, R. 11, 190 feet in depth, enters rock at 159 feet; another near Clarendon Hills, 160 feet in depth, does not enter rock. In each of these wells and in all the wells in that vicinity the drift is mainly a blue till. In the well near Clarendon Hills a very hard till was entered at a depth of 130 feet, which is perhaps an older deposit than the soft till above it.

In the vicinity of Downers Grove several wells have been sunk to a depth of over 100 feet without entering rock. One well enters rock at a depth of 130 feet. In these wells sand is usually found below the blue till at depths of 100 to 120 feet. The Manual of American Waterworks (1897) reports that the public water supply is from two 10-inch deep wells.

Near Lisle the drift is of gravelly constitution, and wells are usually obtained at about 50 feet. A well south of the village, in section 12, is 157 feet in depth and entered rock at about 100 feet. This well was mainly through till.

At Wheaton the public water supply is from a well 178 feet in depth and 10 inches in diameter, which is estimated to yield 300 gallons per minute. The limestone was entered at a depth of 116 feet. About 2 miles northeast of Wheaton, at an equally high elevation (750 feet), rock was entered at a depth of only 70 feet.

Several wells have been sunk in the vicinity of Prospect Park and Lombard, which obtained water from gravel at about 50 feet. The drift in that vicinity is gravelly.

In the vicinity of Turner Junction wells are occasionally sunk to a depth of about 100 feet without encountering rock. A well 3 miles southwest of the village entered rock at a depth of 116 feet. A deep well has been sunk by the Chicago and Northwestern Railway Company at Turner Junction, but no data concerning it have been obtained.

At Naperville wells usually reach water in gravel at a depth of about 30 feet. The drift east and south from this village is gravelly. It ranges in thickness from a few feet up to 100 feet or more. In several places near Naperville limestone quarries have been opened. West from Naperville in the vicinity of Eola the drift is about 100 feet in depth, mainly till.

KANE COUNTY.

GENERAL STATEMENT.

Kane County is situated west of Cook and Dupage, and has an area of 540 square miles. It includes the thriving cities of Elgin and Aurora, and its county seat is Geneva. Fox River flows in a southerly course through the eastern part of the county and is the line of discharge for most of the drainage. The greater part of the county has such imperfect drainage that large areas have been artificially drained. It is in the center of the great dairy district of northeastern Illinois, and the greater part of the county is devoted to dairying. Numerous deep wells have been sunk on the farms, some of them reaching depths of over 200 feet before encountering rock, but in the southeastern part of the county rock is exposed extensively in the bluffs of Fox River and is struck at comparatively shallow depths in the wells. The portion of the county north from the latitude of Geneva is, as previously described, largely occupied by a complicated system of morainic belts, but the southern portion of the county has generally a nearly plane surface. These moraines were formed at the Wisconsin stage of glaciation and, like the Valparaiso morainic system to the east, consist largely of a soft blue till. In several of the deep wells a black soil has been found beneath the blue till, and under this soil a hard till is penetrated. This hard till is apparently of much earlier age than the drift of the Wisconsin stage.

INDIVIDUAL WELLS.

In the northwest township records were obtained of several wells near the village of Hampshire which reach a depth of over 100 feet without entering rock. A well at the brick yards in Hampshire is 102 feet, and one at the Warner Lock Company factory is 118 feet, each being mainly through blue till. On a farm near Hampshire one well reached a depth of 180 feet. On the crest of a moraine east of Hampshire, near Briar Hill Station, at an elevation 975 feet above tide, a well 175 feet in depth is entirely through till except one foot of sand at the bottom. On this same moraine records of several wells were obtained which find water in abundance at a depth of 20 to 35 feet, and the great majority of wells in the township are less than 40 feet in depth.

In the middle township of the north tier the following records of deep wells were obtained:

Deep drift wells in northern Kane County.

	Feet.
Mr. Kelly, sec. 32	130
Mr. Roch, sec. 20	161
Mr. Hunter, sec. 21	106
Near Gilbert Station, in sec. 14	293

In the last of these wells an old soil was penetrated at the base of the blue till, at a depth of 180 to 183 feet, beneath which was a hard till extending to the rock, which was entered at 217 feet.

At Dundee, in the northeast township of the county, wells on the gravel terrace along Fox River are about 60 feet in depth. The public water supply is obtained from springs, but in the part of the village east of Fox River private wells are still in use. Mr. Francis Perry obtained a flowing well in Fox River Valley north of Dundee, near the top of the limestone, at a depth of 181 feet. An old soil was struck at about 155 feet. Water will flow from a pipe 16 feet above the surface. This well is but a short distance from the flowing wells in McHenry County, near Algonquin, reported above.

The city of Elgin obtains its public supply by pumping from Fox River. There are, however, many private wells within the city, and a few deep artesian wells. The wells usually obtain water without entering rock at depths of 50 feet or less. The thickness of the drift in a well at the Elgin Shoe Factory is 123 feet, and an old soil was struck at 108 to 113 feet. The drift above the soil is mainly gravel and cobble, but below it is a reddish till. Usually rock is struck at a depth of less than 100 feet. The following data concerning artesian wells were furnished by W. S. Gamble, city engineer. A well at the Elgin Watch Factory, at an elevation 715 feet above tide, has a depth of 2,026 feet and a diameter of 6 inches. It obtains sulphurous water from St. Peter sandstone at 650 to 700 feet, and soft water from Potsdam at 2,024 feet. A well at the Hospital for the Insane, at an altitude 735 feet above tide, has a depth of 2,230 feet. This also obtains water both from the St. Peter and the Potsdam sandstone. The Elgin Creamery Company have a well 1,400 feet in depth, which obtains water from the Galena limestone at 487 to 514 feet, and from sandstone at 650 to 700, 972, 1,208, and 1,398 feet. The upper veins are more sulphurous than the lower. The Illinois Condensing Company have a well

1,876 feet in depth, which apparently obtains the greater part of its water from the St. Peter sandstone at 650 to 700 feet. The heads at the several wells vary from 716 to 742 feet above tide, the lowest head being at the creamery and the highest at the watch factory well. An analysis of the water from the well at the Hospital for the Insane is published in the Seventeenth Annual Report of this Survey.[1]

A well on the farm of Judge Wilcox, northwest of Elgin, in sec. 4, T. 41, R. 8 E., 127 feet in depth, passed through an old soil at 111 to 114 feet and obtained water without entering rock. The altitude at the well is about 125 feet above Fox River Valley at Elgin, or 850 feet above tide.

Sections of three deep wells were obtained in the township west of Elgin, as follows:

Deep drift wells west of Elgin, Illinois.

	Feet.
Mr. Russell, sec. 12, altitude 825 feet	100
T. Read, sec. 32, altitude 925 feet	219
Well in sec. 35, altitude 900 feet	146

None of the wells enter rock, and in each well the drift is mainly a blue till. In the last one an old soil was passed through at 131 to 137 feet.

In the next township to the west, T. 41, R. 6 E., several flowing wells have been obtained on a plain between morainic ridges at an altitude about 865 to 880 feet, and at depths ranging from 56 to 86 feet, as follows:

Flowing wells from drift in western Kane County.

	Feet.
Sec. 3, altitude 875 feet	75
C. B. Godfrey, sec. 15, altitude 880 feet	72
G. H. Brown, sec. 22, altitude 875 feet	64
D. W. Pierce, sec. 27, altitude 875 feet	70
E. E. Barry, sec. 27, altitude 865 feet	56
S. R. Ellithorp, sec. 27, altitude 875 feet	86

A well at John McDonough's, in sec. 26 of this township, 125 feet in depth, strikes an old soil at 40 feet. This soil is probably referable to the Peorian or post-Iowan interglacial stage. The altitude is not greatly different from that of the flowing wells, yet a flow was not obtained.

A well at the mill in the village of Burlington, 165 feet in depth, is in rock a few feet. A well at a hotel in the village reaches a depth of 100 feet and obtains water in gravel below blue till. In the vicinity of Burlington several wells exceed 100 feet in depth. One in sec. 5 is 114 feet and another 99 feet. One in sec. 17 is 117 feet in depth.

[1] Part II, p. 827.

In the vicinity of Richardson several wells have been sunk to depths of 80 to 120 feet, mainly through till, and obtain water in sand and gravel without entering rock. Mr. Richardson has two wells, one 84 feet, the other 87 feet; Mr. Dayton, one well, 117 feet; Mr. Frank Paul a well 120 feet. Other deep wells in that township range from 50 to 100 feet or more, with an average about 75 feet. Such wells are much stronger than those obtained at shallow depths.

In T. 40, R. 7 E., there is an elevated morainic belt in which the drift probably averages over 200 feet. Each of the wells which enter rock penetrate more than 200 feet of drift, and one well reaches a depth of 336 feet without striking rock. In several wells an old soil is found at the depth of about 200 feet, which in some instances is probably between the Iowan and Illinoian drift or the Sangamon interglacial stage. The following wells serve to illustrate the above statement. At J. Powell's, in sec. 7, altitude about 950 feet, buried soil is struck at 195 to 200 feet and rock is entered at 250 feet. The well is continued about 200 feet into the rock. At M. W. Powell's, in sec. 8, on nearly as elevated a point as the preceding, a well about 500 feet in depth penetrates 234 feet of drift. At a cheese factory in section 19, at an elevation of 950 feet, is a well 336 feet in depth which did not reach rock. An old soil is found below the blue till at 198 to 200 feet, with a greenish subsoil beneath it. A hard till of light gray color sets in at 240 feet and extends to the bottom of the well. Mr. Beith, in sec. 28, has a well 228 feet in depth, which is thought to strike rock at the bottom. The altitude is probably 925 feet. Mr. L. R. Read, in sec. 32, has a well 226 feet in depth, which passed through an old soil at about 180 feet and entered rock at 214 feet. The altitude of the well is about 925 feet.

In the vicinity of St. Charles in T. 40, R. 8 E., several wells have been sunk to a depth of 75 feet or more. One in sec. 1 strikes a black soil below blue till at a depth of 72 to 74 feet, and one on Mr. Dunham's farm, in the east part of the township, passes through a buried soil at 75 to 78 feet. The altitude at these wells is about 750 feet, or nearly 200 feet below that of the deep wells in the township on the west just noted.

At Geneva a well at the court-house was sunk to a depth of 2,500 feet, and the Glucose Company have a well 2,000 feet in depth; this company also has a well 400 feet in depth. No further data concerning these wells have been obtained. The village stands on a gravelly plain at a level

about 40 feet above Fox River. Wells are usually obtained without sinking below the river level. In the vicinity of this village rock is often encountered at depths of but 15 or 20 feet. The drift continues thin southward past Batavia, and many wells in that village enter the rock. Upon passing westward from Fox River the drift increases markedly in thickness within the township limits, though the elevation remains about the same. Several instances of the occurrence of a buried soil were found in this township and the one adjoining it on the west. The following represent the deepest wells in T. 39, R. 8 E., of which sections were obtained; they are all at an altitude of about 750 feet:

Wells near Batavia, Illinois.

In sec. 4, old soil at 120 to 126 feet, gravel at bottom.
East part of Batavia on bluff, rock at 60 feet.
Sec. 24, good wells at 72, 81, and 112 feet in drift.
Mr. Carr, sec. 20, well strikes rock at 43 feet.
Mr. Davenport, sec. 19, three wells in drift at about 100 feet.
Daniel Frydendall, sec. 31, old soil at 80 feet; depth of well 90 feet.

In T. 39, R. 7 E., wells are usually obtained at 40 to 75 feet, but a few exceed 100 feet. The following embrace the deepest of which sections were obtained:

Wells in T. 39, R. 7 E.

Cheese factory at La Fox; depth, 126 feet; rock at 65 feet.
C. G. Morse, sec. 3; depth, 83 feet; no rock struck; lower half a harder till than the upper.
Mr. Outhouse's well, north of Elburn; altitude, about 900 feet; depth, 100 feet.
Tile factory well at Elburn; altitude, 850 feet; depth, 70 feet; old soil at 60 feet.
C. F. Field, sec. 10; altitude, 800 feet; depth, 96 feet; rock at 85 feet.
P. Washburn, sec. 14; altitude, 825 feet; depth, 169 feet. The well is on a gravel knoll 50 feet in height and penetrates: Gravel and sand, 50 feet; brown till, 97 feet; black muck, with log embedded, 2½ feet; yellow till, 7 feet; sand and gravel, with water, 10 feet.
Mr. Sheets, sec. 20; altitude, 750 feet; depth, 47 feet; soil, with wood, at 40 feet.
Blackberry P. O., sec. 21; well from gravel below till at 70 feet.
F. S. Morrill, sec. 21; altitude, 750 feet; depth, 60 feet; mainly blue till.
Mr. Kigling, sec. 22; altitude, 750 feet; depth, 50 feet; rock at bottom.
D. C. Greene, sec. 22; altitude, 750 feet; depth, 40 feet; wood near bottom.
Johnson's Mound, sec. 15; altitude, 800 feet; depth, 180 feet. The well is on the slope of a knoll 80 feet above bordering plain. Another well passed through a bed of leaves and muck at about the level of the base of the mound. Neither well entered rock.
William Beler, sec. 17; altitude, 750 feet; depth, 46 feet; rock at bottom.
Annis estate, sec. 29; altitude, 700 feet; depth, 66 feet; mainly blue till; wood and black muck at 64 feet. Well is thought to have struck rock at bottom.
Russell Benton, sec. 30; altitude, 700 feet; depth, 75 feet; entirely in gravel.

In the vicinity of Kaneville, as noted above, there is a delta-shaped plain of gravel formed at the western end of an esker (see Pl. XIV). Near the western border the gravel is but 20 feet in depth, but at the eastern border, near the esker, wells 60 feet in depth do not reach the bottom. At

Kaneville wells have a depth of 35 or 40 feet and penetrate both gravel and till. At Charles Benton's, east of Kaneville, in sec. 25, a well 54 feet in depth is thought to have struck rock. It penetrates clay 25 feet, sand 25 feet, gravel 4 feet. Near the center of the township, in sec. 15, a well on a knoll is entirely in gravel to a depth of 44 feet.

In Sugar Grove Township the thickness of drift varies from 16 feet or less up to fully 75 feet. In the village of Sugar Grove the deepest wells are 50 to 70 feet without entering rock. In some instances they are through gravel and in others mainly through till. A well at Mr. Hatch's, in sec. 7, 70 feet in depth, obtains water in gravel at bottom and penetrates alternations of clay and fine sand. Mr. Dorr, in sec. 8, has a well in a basin at the side of an esker which is entirely in clay to a depth of 20 feet. On the borders of the basin the drift is gravelly, like that of the esker. Mr. S. E. Sheppardson, in sec. 16, has a well 75 feet in depth, which is entirely through sand and cemented gravel. Mr. Chapman, near Sugar Grove, has a well 90 feet in depth, which entered rock at 60 feet. It was mainly through till. Mr. Potter, in sec. 32, has a well on a knoll, which reaches a depth of 70 feet without entering rock. The upper 40 feet is gravel and sand; the remainder is sandy till.

At Aurora the public water supply is from a series of deep artesian wells 1,388, 2,270, and 2,255 feet in depth. The first obtains water from the St. Peter and the others from the Potsdam sandstone. The water has a head about 60 feet above the surface, or 710 feet above tide. An analysis of the water from each well appears in the Seventeenth Annual Report of this Survey.[1] The water from the St. Peter sandstone contains a remarkably small amount of saline matter and is of excellent quality for domestic use. The Potsdam water is more saline than the water from the St. Peter sandstone. Private wells are obtained in Aurora and vicinity at about 40 feet in gravel. Rock is extensively exposed along Fox River in the city and below as far as the county limits.

DEKALB COUNTY.

GENERAL STATEMENT.

Dekalb County is situated immediately west of Kane and near the middle of the second tier of counties from the north. It has an area of 650 square miles, and Sycamore is the county seat. The greater portion of

[1] Part II, p. 820.

the county drains northward through the south fork of Kishwaukee River. The southeastern part is tributary to Fox River. Like the counties to the east, it is so imperfectly drained that much artificial drainage has been made, both by surface ditches and by tiling.

The Bloomington morainic system which crosses the central portion in a northeast-southwest direction rises about 100 feet above the district on the outer border. There is on the inner border a gradual descent to the valley of Fox River across a plain dotted with only occasional knolls.

The drift is probably as heavy as in any of the counties of northern Illinois (except perhaps Bureau County), there being in 22 borings which reach rock an average thickness of 151 feet, while 68 other deep wells which do not reach rock show an average of 101 feet. The portion on the north border of the county outside the morainic system has scarcely 50 feet of drift, and as it comprises an area of fully 100 square miles it materially reduces the average for the county. As in the counties to the east, the drift is largely a blue till, and occasional instances of the occurrence of a buried soil near or perhaps below the level of the base of the Wisconsin drift have come to notice.

In a large part of the county dairying is the principal pursuit, and many deep wells have been sunk to supply the stock or to furnish water for the creameries and cheese factories. Many of these wells exceed 100 feet in depth, and wells 200 feet or more in depth are not rare.

INDIVIDUAL WELLS.

In the northwest township of the county there are few deep wells, water usually being obtained at 25 to 40 feet. A well in sec. 36, however, reached a depth of 75 feet without entering rock. At several points within the township the rock outcrops at a level not more than 25 feet below this well mouth, or about 800 feet above tide. A flowing well in sec. 35 is supplied from gravel below till at a depth of 22 feet.

In T. 42, R. 4 E., rock outcrops are nearly continuous along the Kishwaukee Bluffs up to an altitude about 750 feet above tide. A few wells in the vicinity of the river penetrate 40 feet or more of drift. On the south border of the township there is a rise of 100 feet or more to the morainic system referred to above, and wells here exceed 100 feet in depth without reaching rock. One at Mr. Leander Roberts's, in sec. 32, has a depth of 132

feet. Another in the same section, at Mr. Keague's, has a depth of 110 feet.

At Genoa, in the northeast township of the county, the wells are 25 to 60 feet in depth and obtain their supply from gravel below till. A well in sec. 26, near New Lebanon, at an altitude about 850 feet above tide enters rock at 90 feet, and has a depth of 122 feet. The south border of this township is occupied by the outer moraine of the Wisconsin drift, but no records of deep wells were obtained. In the township to the south, however, records of several wells were obtained which show the drift to reach a thickness of 150 to 200 feet or more.

For example, in sec. 9., T. 41, R. 5 E., a well 156 feet in depth does not reach rock and is mainly through blue till. The altitude is about 900 feet. At Mr. Marshall's, in sec. 11, at a similar altitude, a well has a depth of 111 feet. At John Haine's, in sec. 2, a well is obtained at 86 feet. Near the center of the township, in sec. 15, Mr. E. Devine made three unsuccessful borings for water to a depth of about 200 feet without reaching the bottom of the drift. The altitude at the wells is about 875 feet. Four wells in sec. 25 each have a depth of about 125 feet, and a fifth well has a depth of 170 feet. They are all mainly through blue till, and none enter the rock. In secs. 35 and 36 three wells have a depth of about 100 feet, a fourth has a depth of 148 feet, and a fifth a depth of 151 feet, all mainly through blue till.

In T. 41, R. 4 E., records of wells show the depth of drift to exceed 100 feet, while one well in sec. 31 reaches a depth of 113 feet without reaching rock. This well is thought to have passed through an old soil at about 80 feet. Another well in the same section has a depth of 112 feet. The wells of this township are mainly through blue till, but one, in sec. 11, is reported to have passed through 35 feet of yellow till and 10 feet of sand before entering blue till. The well has a depth of 98 feet, and terminates in a cemented gravel.

A portion of township 41, R. 3 E., is outside the above-mentioned morainic system and wells there are seldom more than 80 feet in depth. A well at Dustin post-office, 77 feet in depth, is reported to have struck rock near the bottom. Another, in sec. 8, 76 feet in depth, penetrates about 2 feet of rock at bottom. At a schoolhouse in this section, however, a well strikes rock at 12 feet. The altitude at each of these wells is about 825 feet

above tide. At Deerfield post-office an old soil was found beneath the blue till at a depth of 35 or 40 feet. As this stands outside the Wisconsin drift sheet, the soil is to be referred to an earlier interglacial stage than that immediately preceding the Wisconsin stage of glaciation, probably the Sangamon stage. A well on the moraine in sec. 27, about 75 feet higher than Deerfield, enters a black soil at a depth of 125 to 130 feet, or at nearly the same level as that at Deerfield, and perhaps to be referred also to the Sangamon interglacial stage. The following records of deep wells were obtained along the moraine in the southeast part of this township:

Wells in T. 41, R. 3 E.

	Feet.
Mr. Casey, sec. 13, altitude 875 feet	130
John Lloyd, sec. 27, altitude 900 feet	130
Sergis Lloyd, sec. 34, altitude 900 feet	190
James Gibson, sec. 23, altitude 850 feet	90
James Renwick, sec. 28, altitude 900 feet, enters rock at 230 feet	230

In T. 40, R. 3 E., a well in sec. 3, 183 feet in depth, enters rock at 176 feet. The altitude of the well mouth is about 900 feet. A well in sec. 20, 109 feet in depth, is reported to have passed through a black soil near the bottom. The altitude is about 875 feet. A well a mile east from this reached a depth of 123 feet.

In T. 40, R. 4 E., records of several wells which reach rock were obtained. One at Mr. Barlow's, in sec. 31, 153 feet in depth, enters rock at 140 feet. One at Mr. Gurler's, in sec. 32, also enters rock at about 140 feet. The altitude at these wells is 860 to 875 feet. A well at William Barr's, in sec. 31, at similar altitude, failed to reach rock at 183 feet. At Dekalb one of the artesian wells reaches rock at 126 feet, another at 195 feet, and another at 309 feet. South of Dekalb, in sec. 33, a well enters rock at 225 feet. The altitude of these wells in the vicinity of Dekalb is between 865 and 900 feet. Records were obtained of seven wells between Dekalb and Malta having a depth of about 100 feet each, and one well having a depth of 150 feet, none of which enter rock.

The city water supply of Dekalb is obtained from a well 890 feet in depth, which terminates in the St. Peter sandstone. Several other deep wells have been made in the city which terminate in that sandstone. A well at the public square was drilled to a depth of 2,470 feet and terminated in the Potsdam sandstone. Mr. Elwood sunk a well near Dekalb to a depth of 700 feet. None of the wells mentioned overflow. The well at

the city waterworks stands about 65 feet below the surface. It is probable that all obtain water from horizons above the St. Peter as well as from that sandstone. The well at the public square penetrated till 145 feet, below which there was 50 feet of sand and gravel. The well in sec. 33, noted above, penetrated a till, mainly of bluish color, 145 feet; sand, 20 feet; blue till, 59 feet. Mr. Elwood's well had about 100 feet of till at surface; the remaining 200 feet was mainly sand and gravel.

The city water supply at Sycamore is obtained from several flowing wells, which obtain water at a depth of about 65 feet, from gravel beds below blue till. There are several other flowing wells of similar depth along the Kishwaukee River Valley in the vicinity of Sycamore. Wells are usually obtained in this township at depths of 50 to 85 feet, there being apparently a sheet of gravel and sand below blue till at this horizon.

In the western part of Dekalb County, in T. 39, Rs. 3 and 4 E., several wells have been sunk to the rock, as follows:

Wells in western Dekalb County that reach rock.

Locality.	Altitude.	Depth.
	Feet.	*Feet.*
In sec. 1, T. 39, R. 3 E	875	224
Wm. Keast, sec. 4, R. 3 E	900	170
Holton Brue, sec. 11, R. 3 E	900	260
Theodore Burgh, sec. 19, R. 3 E	925	228
Theodore Burgh, sec. 19, R. 3 E	925	200
John Watson, sec. 28, R. 3 E	890	162
A. W. Howard, sec. 20, R. 3 E	925	175
Andrew Nicholson, sec. 20, R. 3 E	925	199
H. Gerler, sec. 5, T. 39, R. 4 E	860	140

All these wells, with the exception of Mr. Nicholson's, terminated after penetrating rock less than 10 feet. But Mr. Nicholson's had penetrated 25 feet of rock at the depth above given. A boring in sec. 7, T. 39, R. 3 E., at an altitude about 925 feet, reached a depth of 230 feet without entering rock or obtaining water. Another boring on the same farm obtained water in gravel at a depth of 192 feet. A well in sec. 9 obtained water in gravel at a depth of 172 feet.

In T. 38, R. 3 E., a well in sec. 8 strikes rock at 152 feet, though located on an elevated part of the moraine nearly 950 feet above tide. Several other tubular wells in that vicinity reach rock at depths of less

than 200 feet, but one well reached a depth of 212 feet without encountering rock. Two wells in the west part of the township, on the farms of Taylor Thompson and William Storey, at altitudes about 950 feet, struck an inflammable gas in gravel at depths of 125 to 150 feet. The drift is mainly till above this gravel. Strong wells are obtained from gravel in that vicinity at 100 to 150 feet.

On the plain in the southeast part of the county wells are usually obtained at depths of 30 or 40 feet. The railroad well at Hinckley, however, was sunk to a depth of 190 feet and entered rock at about 100 feet. The altitude is 750 feet at this well. At Sandwich, where the altitude is only 655 feet, the wells for the public water supply are sunk to a depth of 113 feet without entering rock. Several tubular wells are driven in the bottom of a large well. Private wells in Sandwich and vicinity usually obtain an abundant supply at about 30 feet.

In the southwest part of the county several flowing wells have been obtained from the drift at depths of less than 30 feet. Ten such wells have been made on sec. 32, T. 37, R. 3 E., whose depths are but 22 to 27 feet. A well in sec. 31 is 24 feet. The altitude at these wells is about 725 feet above tide. This flowing well district extends southward to Earlville in Lasalle County. The absorption area is probably from the moraine on the northwest. A well in sec. 2, T. 37, R. 3 E., 67 feet in depth, passed through an old soil at 55 to 60 feet. The altitude at the well is about 800 feet.

OGLE COUNTY.

GENERAL STATEMENT.

Ogle County is situated west of the northern part of Dekalb County, and south of Winnebago and Stephenson counties. It has an area of 780 square miles, and Oregon is the county seat. Rock River traverses the county nearly centrally in a course west of south, and the county is drained by small tributaries of that stream. The greater part of the county is covered but thinly with drift, and preglacial ridges and valleys are in many cases readily traced. The outer moraine of the Wisconsin drift touches the southeast corner of the county, and the drift there is 250 feet or more in thickness. The large preglacial valley, thought to be the old course of Rock River, traverses the eastern part of the county in a north to south

direction. It is filled nearly to the level of the bluffs, and judging by the distance to rock in portions of the valley to the north and south, there is probably not less than 400 feet of drift filling. Along the present course of Rock River there are continuous bluffs rising to heights varying from 75 up to fully 200 feet.

On the uplands, in fully three-fourths of the county, wells commonly enter the rock at 10 to 40 feet, and obtain water at depths ranging from 50 feet up to about 300 feet. Along the lines of preglacial valleys water is usually obtained at a shallow depth in gravel. There are belts of gravelly drift of esker type in the western part of this county similar to those in Stephenson County on the north, and with a similar east to west trend. Aside from these gravelly strips the drift is usually a compact till. There are, however, as in Stephenson and Winnebago counties, many places where it is made up largely of coarse stony material. In the portion outside the Wisconsin drift there are two drift sheets of widely different age. The later of these, the Iowan, appears to extend but little west of Rock River, thus leaving only the Illinoian, in the western part of the county, unless a sheet older than Illinoian is found to be present.

INDIVIDUAL WELLS.

In the northwest part of the county, in the vicinity of Foreston, a till sheet 30 to 40 feet in thickness is generally present. Some of the wells are obtained without entering the rock, but the stronger wells are usually drilled into the limestone. The public water supply at Foreston is obtained from a well 300 feet in depth, in which water rises within 20 feet of the surface. The private wells are 35 to 80 feet in depth.

At Mount Morris the public supply is from a well 502 feet in depth, whose head is nearly 200 feet below the surface and near the top of the St. Peter sandstone.

At Adeline the drift is gravelly, the village being situated on a plexus of knolls and ridges associated with an esker which leads westward along Leaf River. Wells here obtain water at depths of 30 to 75 feet in gravel.

At Hazelhurst, on the west border of the county, there is an esker in which a well was sunk to a depth of 135 feet before striking rock, though the well mouth is 50 feet below the highest part of the esker. Between

Hazelhurst and Polo rock is usually entered at 20 feet or less and the drift is of variable constitution, there being abrupt changes from gravel or sand to till. There is a general capping of loess in that vicinity 6 or 7 feet in depth.

The public water supply at Polo is obtained from a well 2,100 feet in depth, which terminates in the Potsdam sandstone. It is situated in a creek valley, and has but 37 feet of drift. The water is of pleasant taste and is obtained in sufficient quantity for the needs of the town. A well at French's tile yard at Polo penetrates about 80 feet of drift. The upper 13 feet is loess and sandy material, but the remainder is a compact till. East of Polo, on the divide between Elkhorn and Pine creeks, there are several wells which penetrate about 60 feet of drift. They are in a blue till from 20 feet downward to the rock.

At Stratford the village well is 45 feet in depth without entering rock. The railway cuttings immediately east of this village expose two sheets of till separated by a fossiliferous silt. The upper sheet as stated above (p. 138) is apparently much younger than the lower and is probably of Iowan age. Within a mile east of Stratford rock ledges occur at an elevation as high as the railway station (820 feet).

At Oregon the wells range in depth from 20 to fully 200 feet, but are usually about 30 feet. The public water supply was pumped from Rock River until recently, but the Manual of American Waterworks (1897) reports the present supply to be from wells. A railway cutting between Oregon and Mount Morris exposes a buried soil below till at a depth of about 25 feet. This probably separates the Iowan from the Illinoian till sheet.

At the village of Grand Detour wells on a terrace in the valley of Rock River obtain water in gravel at a depth of 20 feet.

At the village of Byron, which is situated on a terrace standing about 50 to 55 feet above Rock River, wells are usually sunk through a gravelly sand to the level of the river.

In the vicinity of Stillman Valley the drift is gravelly, and wells are usually obtained at a depth of 25 feet or less. On the uplands bordering the valley in which this village is situated rock is usually struck at a depth of 10 or 15 feet.

At Davis Junction a town well 53 feet in depth enters rock at 18 feet, and the rock outcrops in many places toward the south. West and north from Davis Junction wells usually penetrate 50 to 80 feet of drift. A well made by F. H. Baker, $1\frac{1}{2}$ miles west of Davis Junction, is 190 feet in depth and strikes rock at about 80 feet. Northeast and east from this village wells reach a depth of over 100 feet without entering rock, this being the position of the old valley of Rock River referred to above. The deepest well noted is at Mr. Kerr's, in sec. 11, which obtains water from gravel at a depth of 120 feet. There appears to be a heavy sheet of till along this preglacial valley, wells 80 to 120 feet in depth being mainly through that deposit.

At Monroe, which is situated on the east side of the old Rock River Valley, rock is usually struck at 5 or 10 feet, but Mr. Tyler's well penetrated 44 feet of drift before entering rock. The railway cutting immediately west of Monroe also exposes drift to a depth of over 30 feet.

Records of several wells were obtained in secs. 27, 28, 29, 30, 31, 32, 33, and 34, T. 42, R. 2 E., which are about 30 feet in depth, and but one well enters rock. East from these sections as far as the county line rock is usually entered at a depth of 10 to 20 feet.

Two wells in sec. 2, T. 41, R. 2 E., enter an old soil below till at a depth of 20 to 22 feet, which is thought to separate the Iowan sheet from an underlying older one. This soil in all probability represents the Sangamon interglacial stage. About 2 miles south from these wells, at James Ashbrook's, a black muck was struck at 67 feet, which yields an inflammable gas. The altitude at each of these wells is about 780 feet above tide and the buried soils are probably all referable to the same stage.

In the vicinity of Lindenwood rock is struck at slight depth (12 to 25 feet). The preglacial valley of Rock River appears to lie entirely north and east of this village. A well at William Stocking's, near this village, in sec. 1, T. 41, R. 1 E., reached a depth of 100 feet without entering rock. It is probably over the line of a tributary of the Rock River Valley, for neighboring wells enter rock at 12 to 30 feet.

In the vicinity of Kings Station, and thence westward past Paines Point, wells usually enter rock at about 10 feet and obtain water at 30 to 50 feet.

At Rochelle the public water supply is obtained from springs issuing from an old rock quarry. Wells are usually obtained at 30 or 40 feet and

enter limestone at about 10 feet. The old valley of Rock River passes east of this city.

At Creston, which is situated on the outer moraine of the Wisconsin drift, a well at the tile factory, 256 feet in depth, enters rock at 250 feet. Several other wells in this village and vicinity are 150 feet, but probably the majority of wells average not more than 50 feet. They are mainly through a soft blue till.

LEE COUNTY.

GENERAL STATEMENT.

Lee County is situated south of Ogle and west of the southern portion of Dekalb. It has an area of 740 square miles, and Dixon is the county seat. Rock River crosses the northwest corner, but drains by direct tributaries only a small portion of the county. The central and southwestern portions drain into Green River, the main southern tributary of Rock River. The southeastern portion of the county is drained by Bureau Creek, a tributary of the Illinois. The portion drained by Green River is largely a marsh, but artificial drainage has brought much of it under cultivation.

The outer morainic system of the Wisconsin drift occupies the eastern and southern borders of the county, and stands 100 to 150 feet or more above the neighboring portions of the Green River marsh on its outer border. The preglacial Rock River apparently passed through this portion of the county. It is probable that where the elevated portions of the moraine coincide with this old valley there is not less than 600 feet of drift, the rock floor of the old valley being known to be at a level that much below the crest of the moraine. Northwestward from the Green River marsh the drift is generally of slight depth, many wells entering rock at 25 feet or less, while outcrops of the limestone are common on nearly all the streams in that part of the county.

Wells are usually obtained at moderate depths in the rock, seldom more than 50 feet. On the moraine in the eastern and southern portion of the county the wells in several instances exceed 200 feet in depth without entering rock, and in portions of the Green River marsh the drift is known to exceed 200 feet. The usual depth of wells on the moraine is, however, not more than 100 feet, there being considerable sand and gravel associated with the till which forms the body of the drift.

INDIVIDUAL WELLS.

At Dixon the public water supply is obtained from three artesian wells, 1,637, 1,710, and 1,810 feet in depth, which terminate in the Potsdam sandstone. The wells overflow into a reservoir, from which the water is pumped to a standpipe. An analysis of the water, published in the Seventeenth Annual Report of this Survey,[1] shows a very small amount of salt and a moderate degree of hardness. The water is considered of pleasant taste and excellent quality. The wells are cased only about 50 feet. The water in each well has a temperature 55° F.

At Nachusa wells are usually obtained at about 30 feet without entering rock. A well one mile northwest of the village reached a depth of 95 feet without striking rock. Within a half mile of this well, however, rock outcrops at a higher elevation than the well mouth.

At Franklin Grove, and also at Ashton, wells usually enter rock at 30 or 40 feet, and there are numerous outcrops of rock in that vicinity. In several instances coal has been found in the drift in the vicinity of Ashton. As this point is north of the border of the coal field, it suggests a northwestward movement of the ice in this region, though the occurrence of coal here may perhaps be due to the presence of outliers north of the main coal field. As indicated below, coal apparently underlies the southeast corner of this county.

The drift is thin over the southern half of T. 39, R. 1 E., and northern half of T. 38, R. 1 E., but north and east from this locality wells occasionally reach depths of 50 and even 100 feet without entering rock. The deepest section of such a well, noted in T. 39, is that of Robert Peile, in sec. 23, which reached a depth of 108 feet. The well has the following section:

Section of Peile well in T. 39, R. 1 E.

	Feet.
Soil and brown till	10
Gravel	1
Blue till	20
Gravel	5
Brownish till, with occasional gravelly beds	72

The upper 36 feet of this section should perhaps be referred to the Iowan stage of glaciation. Blue till is occasionally entered in that vicinity at only 6 or 7 feet below the surface, or at a much shallower depth than in the drift of the Illinoian stage.

[1] Part II, p. 827.

At Amboy shallow wells are obtained at 12 to 20 feet, many of which enter the rock. At the waterworks the supply is obtained from an artesian well 2,000 feet in depth. Water veins which overflow were struck at 390, 1,100, and 1,700 feet. The lower veins do not increase the head, but evidently increase the quantity, for the upper flows could be readily lowered by pumping, while the lower ones can not.

The discussion of wells on the moraine which follows begins in the northeast part of the county, from which point the moraine is followed southwestward.

Table of deep wells in eastern and southern Lee County, Illinois.

Location.	Altitude (above tide).	Depth.	Remarks
	Feet.	*Feet.*	
Sec. 3, T. 39, R. 2 E	925	168	In gravel below till.
Sec. 34, T. 39, R. 2 E	925	200	Old soil at 100 feet; no rock struck.
Sec. 32, T. 39, R. 2 E	875	45	Gravel below till.
Sec. 15, T. 38, R. 2 E	950	200	Gravel below till.
Sec. 12, T. 38, R. 2 E	950	50	Gravel below till.
Sec. 16, T. 38, R. 2 E	875	40	Entirely in gravel.
Sec. 14, T. 38, R. 2 E	875	60	Mainly sandy drift.
Sec. 36, T. 38, R. 2 E	950	217	In gravel below till; no rock.
Sec. 33, T. 38, R. 1 E	820	114	No rock; old soil at 80 feet.
Sec. 18, T. 37, R. 2 E	800	115	Driller reports coal at bottom.
3 miles S. of Pawpaw	800	100	Driller reports buried soil at 80 feet, sandstone at 90 feet, and coal at about 100 feet.
Sec. 36, T. 37, R. 2 E	800	155	Old soil at 78 to 81 feet; drift mainly till; no rock struck.
Sec. 35, T. 37, R. 2 E	775	100	Mainly sand and gravel; no rock.
Sec. 19, T. 37, R. 2 E	950	287	Old well, 45 feet; sand, 5 feet; blue till, 190 feet; greenish clay, 19 feet; rock (?), 6 feet; blue till, 15 feet; cemented gravel, 1½ feet; loose gravel at bottom.
Sec. 32, T. 37, R. 2 E	925	200	Not known whether rock was struck.
Sec. 30, T. 38, R. 1 E	800	84	Soil and wood near bottom.
Sec. 29, T. 38, R. 1 E	800	90	Wood and leaves at bottom.
Sec. 12, T. 19, R. 11 E	935	218	Little, if any, rock penetrated.
Sec. 2, T. 19, R. 8 E	660	200	No rock struck.
Sec. 36, T. 19, R. 8 E	800	200	Terminates in sand. Wood, with inflammable gas, at 140 feet.
Sec. 14, T. 20, R. 8 E	700	105	No rock; beds of sand and gravel in blue till.
Sec. 28, T. 20, R. 8 E	690	166	No rock struck; sand, 25 feet; remainder blue till.

The last edition of the Manual of American Waterworks (1897) reports that the village of Pawpaw, in the southeast part of the county, obtains its public supply from an artesian well 1,018 feet in depth.

CARROLL COUNTY.

GENERAL STATEMENT.

Carroll County borders the Mississippi River in the second tier of counties from the north and has an area of 440 square miles, with Mount Carroll as the county seat. The northwestern portion is drained by Plum River and Carroll Creek, its main tributary, directly to the Mississippi Valley at Savanna. The southeastern portion is drained southward through Rock and Elkhorn creeks into Rock River. The surface is rolling and drainage good throughout the upland portion of the county.

With the exception of the northwest corner, which is unglaciated, this county is covered with a sheet of drift of moderate depth. Records of 14 wells on the uplands, distributed widely over the county, show an average of 54 feet to the rock, the greatest depth being about 100 feet. In the Mississippi Valley below Savanna there is probably 150 feet or more of drift, as indicated by borings at Sabula, Iowa, and Fulton, Illinois, which reach a level nearly 150 feet below the Mississippi before entering rock. The valley drift is largely sand or fine gravel. The drift on the uplands is in places a gravelly or stony material, but usually has a large clay admixture, such as characterizes the typical till.

In every township of the uplands numerous wells enter the rock, but a still larger number obtain water from gravel or sand associated with till at various depths from 20 feet or less up to about 100 feet.

INDIVIDUAL WELLS.

At Savanna the public water supply is from an artesian well 1,430 feet in depth, which terminates in the Potsdam sandstone. It discharges at the rate of 500 gallons per minute and has a pressure of 35 pounds per square inch at the level of the well mouth, about 600 feet above tide. The head is, therefore, about 675 feet.

At Mount Carroll the public water supply is from a well 2,502 feet in depth, which has a head sufficient to rise nearly to the well mouth, about 700 feet above tide. Water was struck in the limestone at 65 to 100

feet, but a much stronger supply was struck at about 1,200 feet. The drift is largely gravel and has a depth of 61 feet The well is situated in a valley about 100 feet below the bordering uplands, and rock appears in the uplands near by at a level fully 50 feet above the well mouth. A well at the railway station in Mount Carroll reaches rock at a depth of 60 feet. The altitude there is 816 feet above tide. This well penetrated a complex series of beds of gravel, sand, and till. A boring at William Petty's, 4 miles southwest of Mount Carroll, is reported to have penetrated about 300 feet of drift. On the farm of R. Hostetter, 3 miles southeast of Mount Carroll, a well strikes rock at the depth of 72 feet; the drift is mainly a blue clay. Hon. James Shaw reports a well section near Mount Carroll, which struck a black mucky clay, apparently a soil, at a depth of about 50 feet; another well at the farm of F. O'Neal, 3 miles from Mount Carroll, passed through a soil and wood at 15 to 20 feet. The latter is perhaps at the junction of the loess with the underlying glacial drift, but the former penetrated a sheet of glacial drift above the soil, and its section is as follows:[1]

Section of a well near Mount Carroll, Illinois.

	Feet.
Soil, yellow and blue clays	15
Reddish clay and gravel	15
Tough blue clay	2
Coarse gravel	3
Yellow sand	11
Black mucky clay	5

A deep artesian well has been sunk in a creek valley about 4 miles south of Mount Carroll, which overflows with considerable force. No further data have been obtained.

At Lanark the public water supply is from a well obtained near the top of the limestone at about 100 feet. The following drift beds were penetrated: Clay, 12 or 15 feet; gravel and sand, 12 or 15 feet; blue clay, with few pebbles, 75 feet. A well at L. Sprecher's, 1 mile west of Lanark, enters rock at about 100 feet and there obtains water. In the township east of Lanark wells are reported to differ greatly within short distances in the amount of drift penetrated, some entering rock at about 20 feet while others penetrate 100 feet or more of drift.

[1] Geology of Illinois, Vol. V, p. 80.

At Shannon wells near the railway station enter rock at 15 or 20 feet, but on a rock ridge in the south part of the village, at an elevation probably 30 feet higher than the railway station, or 950 feet above tide, rock is entered at 8 or 10 feet. The public water supply is reported by Manual of American Waterworks (1897) to be from a drilled well.

In the south part of the county, in the vicinity of Ideal, several wells enter rock at 30 or 40 feet. The loess in that locality is about 15 feet in thickness. At Argo, in Johnson Creek Valley, 125 feet of sand and gravel were penetrated before striking rock.

At Fair Haven (altitude about 875 feet) the creamery well has the following section, furnished by the driller, Mr. J. Schlemming, of Chadwick:

Section of well at Fair Haven, Carroll County, Illinois.

	Feet.
Drift	40
Niagara limestone and chert	60
Mainly shale	210
Gray limestone	15
Total	325

Mr. Schlemming states that the wells in the south part of Fair Haven Township often obtain water in the cherty beds above the shale; otherwise they must be sunk to limestone beds beneath the shale.

At Chadwick the public water supply is from a well 215 feet in depth, which enters rock at 59 feet. The rock is entirely a gray limestone and appears to be the same formation which was entered near the bottom of the Fair Haven well. The drift is mainly clay, there being but little sand or gravel. The head is about 40 feet below the level of Chadwick railway station, or 735 feet above tide. The well has a diameter of $5\frac{5}{8}$ inches and is estimated to furnish 400 barrels per hour.

In the vicinity of Milledgeville the best wells are about 180 feet in depth and are probably from Galena limestone. The town well has a depth of only 80 feet and enters Galena limestone at 12 feet. Many wells obtain weak veins of water at about 30 feet near the top of the limestone.

WHITESIDE COUNTY.

GENERAL STATEMENT.

Whiteside County borders the Mississippi River in the third tier of counties from the north line of the State and has an area of 700 square miles, with Morrison as its county seat. Rock River leads through the county from the eastern border to the southwest corner and receives the drainage of the greater part of the county, only a narrow belt on the northwest being directly tributary to the Mississippi. The southern half of the county is a lowland tract standing but little above the level of Rock River, its general elevation being about 650 feet above tide. The northern and western portions have an altitude corresponding with that of the uplands in Carroll and Ogle counties, the altitude of a considerable part being above 800 feet and in places reaching nearly 900 feet. Two narrow lowland tracts, resembling river valleys, connect the Mississippi River with the lowland bordering Rock River, one of which, on the southwest border of the county, is known as Meredosia Slough, and one, leading from near Fulton to Fenton, as Cattail Slough (see Pl. XVIII). These sloughs stand so little above the level of the Mississippi and Rock rivers that they are occupied in flood stages of either stream, and the direction of flow depends upon the stream which chances to have the higher stage.

On the uplands the drift is of variable thickness, but is generally thinner in the northern and northeastern portions than in the western portion of the county. The general thickness, however, seldom falls below 50 feet even on ridges. In the western portion, from near Fulton southward past Garden Plain to Erie, there appears to be an average thickness of fully 150 feet. Were this drift removed, the elevation would differ but little from that of the lowland tracts bordering Rock River, for rock is often found at slight depth beneath these lowlands except in the southeast portion of the county. In the uplands of the northern portion of the county some wells are sunk to considerable depth in the rock. In the western portion they usually obtain water in the drift or at slight depth in the rock. On the lowlands north of Rock River the wells are generally shallow and often enter the rock a few feet. In the southeastern part of the county much of the land has not been brought under cultivation, the sur-

face being either sandy or marshy, and comparatively few deep wells have been sunk. Deep wells in the neighboring portions of Lee and Bureau counties penetrate over 200 feet of drift, and it is probable that a similar depth extends over three or four townships in the southeast part of this county.

INDIVIDUAL WELLS.

At Fulton, in the Mississippi Valley, in the northwest corner of the county, the city water supply is from an artesian well 1,246 feet in depth, which terminates in the Potsdam sandstone. A flow of sulphurous water was struck at about 475 feet. Another flow was obtained from the Potsdam at 940 to 1,050 feet. The head is sufficient to carry the water 60 feet above the surface, or about 655 feet above tide. The well has a diameter of 5 inches and an estimated capacity of 300 gallons per minute. The drift at this well is reported by the engineer of waterworks to be 125 feet, but Prof. J. A. Udden obtained a record which is thought to be more reliable in which the drift is reported to be about 200 feet. Shallow wells in the valley in the vicinity of Fulton are obtained at a depth of about 25 feet. Wells on an island-like upland in the north part of the city, standing 100 feet more or less above the river, are sunk to depths of 60 or 75 feet. They enter rock at the base of the loess at about 25 to 30 feet, there being but little glacial drift.

Near Ustick rock is usually entered on ridges at about 50 feet and in places at much less depth, but occasionally a greater depth is found. A well on a ridge one-fourth mile south of Ustick did not reach rock at 200 feet. Farther east, in the elevated part of the county, wells enter rock at 50 to 75 feet and not infrequently reach depths of 100 to 150 feet or more.

In the vicinity of Garden Plain, in T. 21, R. 3 E., wells enter a bed of black muck containing wood at a depth of 30 or 40 feet. The material above the muck is usually free from pebbles and is of the coarseness of sand rather than of loess. There appears to be no till or other strictly glacial material above the soil Beneath this muck a blue till is entered, which extends usually to the rock at a level 65 to 100 feet or more below the surface. East and south from Garden Plain the distance to the blue till varies from 25 feet or less up to about 50 feet. A well in sec. 24 enters blue till

at 25 feet and rock at 67 feet. A well in sec. 26 entered rock at 78 feet without penetrating any blue clay, the following being its section:

Section of a well near Garden Plain, Illinois.

	Feet.
Loess	15
Fine sand	15
Coarse sand, becoming gravelly near bottom	48
Rock	5

A well in sec. 11, 106 feet in depth, enters rock at about 100 feet. Professor Udden reports that in secs. 1 and 2 of this township rock is struck at a depth of only 30 feet.

In the vicinity of Union Grove and thence east to Morrison the wells usually enter rock at less than 30 feet, but a well in sec. 18, 70 feet in depth, penetrates rock only 2 feet. It is entirely through sand, and is reported to have penetrated snail shells near the base of the sand. A well near the center of sec. 12 enters rock at 63 feet, and is reported to be entirely through loess and sand, except 3 feet of gravel at the top of the rock (Udden).

The public water supply for the city of Morrison is obtained from springs in Rock Creek Valley. An artesian well was sunk at this city to a depth of 1,190 feet. Mr. S. D. Gossert, editor of the Whiteside Sentinel, reports that the head is sufficient to carry the water 15 feet above the surface, but the well was not in use at the time his communication was received (August, 1895). Mr. Gossert reports that the wells in the vicinity of Morrison range from 35 to about 80 feet in depth, and are in nearly all cases obtained from the rock. Southeast of Morrison, near the south border of the township, the present writer obtained records of several wells which do not enter rock at depths of 40 or 50 feet, but other wells in that vicinity enter rock at about 20 feet.

Rock outcrops extensively in the vicinity of Rock Falls and Sterling. But a well in sec. 33 of this township is reported by Professor Udden to penetrate drift 84 feet and to terminate in limestone at 313 feet. With the exception of 5 feet near the bottom of the drift, there was no clay in this well section, the greater part being sand and fine gravel.

The public water supply at Sterling and also at Rock Falls is obtained from an artesian well 1,450 feet in depth, which terminates in the Potsdam sandstone.[1] The well overflows at an elevation about 670 feet above tide

[1] The Manual of American Waterworks, 1897, reports a depth of 1,600 feet.

and has an estimated capacity of 350 gallons per minute. An analysis is given in the Seventeenth Annual Report of this Survey,[1] which shows it to be a moderately hard water with very little salinity. Private wells in the vicinity of Sterling range in depth from 25 to 100 feet, with an average about 35 feet. Only the shallowest ones are obtained in gravel, the remainder being from limestone.

In the vicinity of Prophetstown wells are usually obtained at less than 50 feet without entering rock and are mainly through gravel. A short distance northwest from Prophetstown, on the north side of Rock River, rock is found at slight depth and it occasionally outcrops. But east from Prophetstown as far as the county limits (16 miles) no records of wells reaching rock were obtained.

In T. 20, R. 3 E., which is situated near the western border of the county, the following sections of deep wells were obtained:

Wells in T. 20, R. 3 E., Whiteside County, Illinois.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
F. S. Hunt, sec. 3	750	85	Loess and sand, 20 feet; fine blue sand, 25 or 30 feet; blue till, 35 or 40 feet; gravel and water, 5 feet.
Chester Ege, sec. 4	740	163	Water from gravel at 160–163 feet; rock (?) at bottom.
Schoolhouse, sec. 4	740	193	Loess, 15 or 20 feet; blue sand, 10 or 15 feet; blue till (mainly), 160 feet. Thought to have struck rock at bottom.
Mr. Huggins, sec. 9	740	160	Loess, 15 or 20 feet; blue sand, 10 or 15 feet; blue till with thin gravel beds, 120 feet; white sand, 10 feet. Thought to have struck rock.
William Roland, sec. 10	740	147	Little if any rock penetrated.
S. Miller, sec. 21	625	65	Limestone at bottom.
Wm. Miller, sec. 21	690	150	Limestone at bottom.
J. Marshall, sec. 22	630	78	Terminates in gravel.
Sec. 33	680	70	Several wells 70 feet deep do not enter rock.
I. Drury, sec. 34	720	139	Rock at 126 feet.

In the vicinity of Erie wells reach a depth of about 40 feet without entering rock. The majority obtain water at 20 or 30 feet. They are mainly through a fine sand. A well in section 3 of this township, 47 feet

[1] Part II, p. 828.

in depth, penetrates 10 feet of clay, below which it is entirely in sand. A well in section 22, altitude 580 feet, enters rock at about 27 feet (Udden). Professor Udden reports the following sections of deep wells south of Rock River in the vicinity of Spring Hill:[1]

Wells near Spring Hill, Illinois.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
A. J. Seeley, sec. 1	630	70	Rock at bottom.
Hervy Stull, sec. 5	590	40	No rock struck.
A. Colbert, sec. 20	660	117	Bowlder clay, 75 feet; sand, 42 feet.
Spring Hill post-office	640	100	No rock struck.
B. B. Brooks, sec. 29	660	90	Loess, 20 feet; blue clay, 60 feet; gravel at bottom.
Stanley Fuller, sec. 29	660	130	Sand, 16 feet; blue clay, 90 feet; sand with water, 18 feet; rock, 6 feet.
David Uhrich	660	100	Loess and till, 50 feet; sand, 12 feet; blue till, 30 feet; sand, 8 feet.
E. Crozier, sec. 32	650	100	Clay, 60 feet; sand, 40 feet.
A. Crozier, sec. 32	640	101	Yellow clay, 10 feet; blue clay, 30 feet; sand at bottom.
Sec. 30, near center	640	90	"Hardpan" at bottom, perhaps shale.
Mr. Bryant, sec. 36	625	60	Entirely through sand.

A well driller at Prophetstown informed the writer that he had struck rock in one well near Spring Hill at 90 feet, and in another at about 100 feet. Probably the deepest well in the vicinity of Spring Hill is on the farm of Mr. Henry Smead, in sec. 31. This reached a depth of 215 feet, and is thought by Mr. Smead to have terminated in a stony clay, apparently till. As the well mouth is not more than 640 feet above tide, this section indicates the presence of a very deep preglacial valley.

Several families in the village of Spring Hill have obtained a supply of water from a well only 20 feet in depth, sunk on low sandy ground east of the village. A windmill forces the water to a tank, from which the water is distributed through pipes to the dwellings. The total expense, aside from laying pipes, is only $5 per annum for each dwelling. The water thus obtained is but moderately hard, and is preferred to the very hard water obtained from the till encountered by wells in the village. In this connec-

[1] Communicated to the writer.

tion it may be stated that the wells throughout the sand district of the Green River Basin are reported to furnish a water that is less hard than that obtained from the till.

ROCK ISLAND COUNTY.

GENERAL STATEMENT.

Rock Island County occupies a narrow strip bordering the Mississippi River for a distance of about 50 miles, the city of Rock Island, its county seat, being about midway of its western border. The area of the county being but 440 square miles, its average width is less than 10 miles. Rock River divides it into two nearly equal portions and forms the eastern border for about 20 miles in the northern part of the county. Meredosia Slough forms the northern border of the county. Between this slough and the village of Hampton there is an island-like tract of upland standing about 150 feet above the Mississippi River, which at times of high water either in the Mississippi or Rock River is completely encircled by streams. Between this upland and the city of Moline a gravel-filled valley, called "Pleasant Valley," leads across from Rock River to the Mississippi (see Pl. XVIII). Its elevation is but a few feet above the high-water stages of the streams. Between this valley and Rock River is another island-like tract of upland leading from the city of Rock Island eastward to Carbon Cliff, which stands about 150 feet above the Mississippi and Rock rivers. South from Rock River Valley is an upland tract rising gradually southward from an elevation of 150 feet above the river at the bluff to fully 250 feet at the Mercer County line, or to slightly more than 800 feet above tide.

The island-like upland tract northeast from Hampton has a deposit of loess 30 or 40 feet in thickness, beneath which there is blue till extending to the rock, which is usually entered at 100 feet or less. The upland between the city of Rock Island and Carbon Cliff has about 40 feet of loess near the Mississippi, but the thickness decreases eastward to scarcely more than 25 feet at Carbon Cliff. Beneath this loess is a thin sheet of glacial drift, rock usually being struck at 50 to 75 feet. The upland south of Rock River has a loess capping about 25 to 40 feet in thickness on the borders of the Rock and Mississippi rivers, which decreases southward to 15 feet or less at the Mercer County line. On the brow of the Rock and Mississippi River bluffs rock is usually entered in wells at 50 to 60 feet, but on

the more elevated upland near the Mercer County line there is nearly 150 feet of drift, mainly a blue till.

Throughout the county wells usually obtain an abundance of water without entering the rock, though those on the upland are often sunk to depths of 75 or 100 feet. In the valleys northeast of Rock Island wells are usually obtained at depths of 30 or 40 feet without entering rock. Along Rock River and the portion of the Mississippi Valley below Rock Island the drift deposits are thin and wells frequently enter the rock.

INDIVIDUAL WELLS.

The following well sections include the deepest of which records have been obtained aside from the artesian wells. About one-half the sections were collected for the Survey by Prof. J. A Udden, who has kindly furnished them for publication in this place.

Table of wells in Rock Island County.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Sec. 9, T. 19, R. 2 E	700	102	Loess, 30 or 40 feet; till, 60 feet; limestone, a few feet.
Creamery, sec. 15	680	88	Loess, 12 feet; quicksand, 27 feet; black muck with wood, 9 feet; blue clay, 40 feet.
H. Sadoris, sec. 16	700	90	Loess, 30 or 40 feet; blue till, 40 feet; shale and limestone, a few feet.
W. McRoberts, sec. 17	720	107	Loess, 20 feet; sand, 64 feet; rock with gas, 23 feet.
A. Spaid, sec. 17	720	120	Loess, 20 feet; quicksand, 80 feet; gravel, 8 feet; white shale, 12 feet; limestone at bottom.
Mrs. Genung, sec. 21	700	100	Loess, 30 or 40 feet; till, 45 or 50 feet; shale and limestone, a few feet.
H. McCall, sec. 22	710	185	Loess, 20 feet; soil and wood, 5 feet; sandy drift, 70 feet; shale and limestone, 90 feet.
L. Gaylord, sec. 31	670	65	Loess, 40 feet; fine gravel, 25 feet; Coal Measure sandstone at bottom.
H. C. Genung, sec. 35	680	135	Rock entered at about 100 feet.
Sec. 8, T. 19, R. 3 E	575	40	In sand below hard clay.
A. Goodrich, sec. 8	600	67	Rock entered at 55 feet.
Sec. 9, T. 18, R. 2 E	600	38	Limestone at 20 feet.
Sec. 18, T. 18, R. 2 E	670	80	Loess, 30 feet; sand, 40 feet; shale, 10 feet; wood in the sand.

Table of wells in Rock Island County—Continued.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Sec. 12, T. 18, R. 1 E	680	100	Loess, 30 feet; till, etc., 70 feet; sandstone at bottom.
Bluff east of Hampton	680	80	Loess, 30 feet; till, blue near bottom, 50 feet; no rock exposed.
Upland west of Carbon Cliff	650	45	Loess, 25 feet; till, 15 or 20 feet.
Rock Island near Thirty-sixth street.	625	34	Near base of bluff; yellow till, 5 feet; black muck, 1 foot; brown till, 7 feet; blue till, 4 feet; black calcareous fossiliferous silt, 8 feet; black muck, 4 feet; green clay with local pebbles, 5 feet; shale at bottom.
Moline, Seventh avenue and Fifth street.	590	30	Loess beneath pebbly clay at 30 feet.
Secs. 7 and 12, T. 17, Rs. 1 and 2 W.	680	65	Ravines expose loess 45 feet; black soil, 2 feet; till, 12 feet; fossiliferous loess, 6 feet.
Sec. 17, T. 16, R. 2 W	775	105	Loess, 15 feet; yellow till, 15 feet; blue till, 73 feet; sandstone, 2 feet.
Taylor Ridge	796	82	At village well, loess, 15 feet; till, 67 feet; sand at bottom.
W. S. Parks, sec. 15	800	150	Rock struck at 140 feet.
W. H. Wheaton, sec. 34	825	83	Mainly till; no rock struck.
Illinois City	715	40	Loess, 20 feet; black soil, 3 to 5 feet; till, 15 or 20 feet.
Sec. 32, T. 15, R. 5 W	725	130	Ravines expose loess 25 feet; black soil, 2 or 3 feet; till, 90 feet; fossiliferous loess, 12 feet.

The public water supply at Moline and Rock Island is pumped from the Mississippi River. Several artesian wells have been sunk at these cities; also one at Carbon Cliff, and one at Milan. Prof. J. A. Udden has collected a large amount of data concerning the wells and examined the drillings from several of them. The results of his investigations are presented in the Seventeenth Annual Report of this Survey.[1] The public water supply at Milan is from an artesian well, 1,157 feet in depth, which has a head 68 feet above the surface.

[1] Part II, pp. 829–849.

MERCER COUNTY.

GENERAL STATEMENT.

Mercer County borders the Mississippi River immediately south of Rock Island County and has an area of 555 square miles, with Aledo as the county seat. It is drained by Edwards River and Pope Creek, each stream having a westward course entirely across the county. On the immediate borders of the Mississippi the uplands are but 675 to 725 feet above tide, but there is a gradual rise eastward across the county to an altitude of over 800 feet. Very few data concerning the wells have been obtained, the writer having made but a single trip across the county. The drift appears to be much thicker in the northern and eastern portions than in the southern and western portions. In the latter district wells on the uplands often enter rock at 50 feet or less, while in the former, if we may judge by wells in the adjacent portions of Rock Island and Henry counties, the drift has a thickness of about 150 feet. It is probable that the filling along the valley of the Mississippi in the western part of this county is at least 150 feet, for the river there is following the line of a deeply filled preglacial valley.

INDIVIDUAL WELLS.

The public water supply of the city of Aledo is obtained from a well 3,115 feet in depth, which probably is exceeded in depth by but one other well within the limits of the State, a prospect boring for salt water at St. Johns which at last report (March, 1899) had reached a depth of over 3,600 feet. The Aledo well terminates in the Potsdam sandstone and has a head 75 feet below the surface, or about 665 feet above tide. The well is cased only 240 feet from top and 100 feet at 1,705 to 1,805 feet. Water was struck at several levels, two strong veins being found near the base of the drift at 41 and 60 feet from the surface, and others in the Galena and St. Peter and lower strata. The water was not markedly saline until a depth of 2,620 feet had been reached. The temperature is 68° F. The private wells in Aledo and vicinity are obtained at a depth of only 20 feet.

At Keithsburg, in the Mississippi Valley, the public water supply is obtained from wells driven to a depth of 20 or 30 feet in the valley gravel.

A well on a terrace of Edwards River, in sec. 11, T. 14, R. 5 W., entered a bed of peat at a depth of 44 feet, specimens of which were col-

lected by the writer. A well driller at Aledo states that a peaty soil is occasionally struck in the western part of this county at a level lower than the base of the loess, it being in some instances 45 feet below the surface. This is probably the Yarmouth soil of pre-Illinoian age. A soil is also found at the base of the loess, 15 or 20 feet below the surface, which is evidently the Sangamon soil.

The thickest section of drift reported within the county is in a well one-half mile northeast of Joy, where a depth of 70 feet was reached without entering rock. A ravine leading into the Mississippi Valley just north of the county line exposes 130 feet of drift, as noted in the discussion of Rock Island County.

HENRY COUNTY.

GENERAL STATEMENT.

Henry County is situated east of Rock Island and Mercer counties, and has an area of 830 square miles, with Cambridge as the county seat. Rock River forms a portion of its border on the northwest; Green River traverses its northern portion in a westward course, and Edwards River its southern portion. The north part of the county from the vicinity of the Chicago, Rock Island and Pacific Railroad northward is a low sandy area, imperfectly drained by Green River. The remainder of the county is an upland, standing 100 to 200 feet higher than the sandy lowland, a considerable portion being more than 800 feet above tide. A bluff-like rise in part an escarpment of sandstone which appears just south of the line of the Chicago, Rock Island and Pacific Railway is the most conspicuous topographic feature of the county, though it seldom exceeds 100 feet in height, and is coated with drift to an average depth of fully 50 feet.

The drift is generally of moderate depth, though a few wells in the west part of the county have penetrated 150 feet or more. It is probable that the drift is heavy in much of the low area in the north part of the county since it is heavy in the adjacent part of Bureau County; but wells have not been sunk in that district to a sufficient depth to test this question.

INDIVIDUAL WELLS.

The public water supply at the city of Geneseo, in the northwest part of the county, is obtained from an artesian well 2,250 feet in depth, which terminates in the Potsdam sandstone. The well is 6 inches in diameter and

has an estimated capacity of 190 gallons per minute. The head is sufficient to raise the water about 30 feet above the surface, or 675 feet above tide. Several water veins were encountered, as follows: In the Devonian or Upper Silurian limestone, at 140 to 160 feet; Galena, at 950 to 975 feet; Lower Magnesian, at 1,350, 1,450, and 1,590 feet; Potsdam sandstone, at 2,040 to 2,160 feet. The determination of the geological horizons was made by Prof. J. A. Udden, who also has furnished the other data given.

The city of Kewanee, in the southeast part of the county, also obtains its public water supply from artesian wells, two wells being 1,050 feet and a third 1,480 feet in depth. The principal supply of water in all the wells is probably from the St. Peter sandstone at a depth of about 1,000 feet, the upper veins of water being cased out. The head is 150 feet below the surface, or 700 feet above tide, this city being located on an elevated tract about 850 feet above tide. The wells have a combined capacity of about 260 gallons per minute. The water is comparatively soft and of pleasant taste. Its temperature in each well is 65° Fahr. The private wells in Kewanee and vicinity are usually obtained at 40 or 50 feet from gravel below till. The drift at the artesian wells is about 80 feet in depth and mainly till, but at a coal shaft a half mile east of the city, at equally high elevation, rock is entered at 35 feet.

At Galva, in the southern part of the county, at about the same elevation as Kewanee, rock is entered at 30 to 60 feet, but many of the wells obtain an abundance of water in the drift after penetrating a sheet of till. The last edition (1897) of the Manual of American Waterworks reports the public water supply to be from a well. At the brickyards a well has the following section:

Section in brickyard at Galva.

	Feet.
Loess	15
Black soil (Sangamon)	2
Brown till	30
Blue till	8
Sandstone at bottom.	

The soil at the base of the loess is well exposed in the clay pit at the brickyards. A large log was found embedded in this soil, but no specimens were at hand at the time of the writer's visit to the locality.

At Cambridge wells are usually obtained at about 40 feet, in gravel beds below till. Occasionally a well reaches a depth of 75 feet. The drift in that vicinity is about 60 feet in depth, including 15 or 20 feet of loess.

The Manual of American Waterworks reports the public water supply to be from a deep well.

At Andover, about 5 miles southwest of Cambridge, a well penetrates 155 feet of drift, striking rock near the bottom. The lower 20 feet of the drift is sand, the remainder mainly till.

At Lynn Center and vicinity several wells enter rock at about 115 feet. The section usually penetrated is as follows:

Generalized section of wells near Lynn Center.

	Feet.
Loess	15
Yellow till	10 or 15
Blue till, with thin beds of sand	80

At Alpha wells are usually obtained at 15 to 30 feet from a gravelly drift at the base of the loess or near the top of the till, though a few are sunk into the rock. A well at Bolton's sorghum mill enters rock at 75 feet, and several wells southwest of Alpha reach rock at about 70 feet. The drift is mainly blue till.

In the vicinity of Orion several deep wells have been made which show the drift to exceed 100 feet. In one instance rock was struck at 150 feet. A well at the creamery, 130 feet in depth, did not reach rock, water being obtained from sand beneath blue till.

At Annawan, in the east part of the county, a well at the creamery, 223 feet in depth, entered rock at 124 feet. The drift is entirely clay (Udden).

The following sections of farm wells are reported by Professor Udden:

Wells in Henry County, Illinois.

Owner and location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Adam Butzer, sec. 1, T. 18, R. 3 E	650	85	Strikes rock at bottom; mainly through sand.
John Crozier, sec. 7, T. 18, R. 4 E	630	65	No rock struck; upper 30 feet sand, remainder bowlder clay.
William Arnett, sec. 6, T. 18, R. 4 E	630	75	Upper 40 feet clay, remainder sand.
Henry Arnett, sec. 5, T. 18, R. 4 E	645	120	No rock struck.
A. S. Tiffany, sec. 5, T. 16, R. 4 E	610	48	Terminated in gravel.

In the northwest part of T. 15, R. 4 E., at an altitude of 775 feet, several wells 60 feet in depth do not reach the rock.

BUREAU COUNTY.

GENERAL STATEMENT.

Bureau County is situated east of Henry, in the north-central part of the State, its southeast border being at the Illinois River, near the great bend. It has an area of 870 square miles, and Princeton is the county seat. The northwest part of the county is a marshy and sandy district, drained westward by Green River; the central and northeastern portions of the county are drained by Bureau Creek, a tributary of the Illinois; the southwestern portion, which is an elevated district, divides its waters between Green River on the north and Spoon River on the south.

The bulky morainic system forming the outer border of the Wisconsin drift passes southward through the central portion of this county, leaving a belt 10 or 12 miles in average width on the west border of the county, which is outside the limits of the Wisconsin drift. This morainic system constitutes the highest portion of the county, much of its main crest being above 900 feet. Yet it apparently crosses and occupies for a few miles the deep preglacial valley through which Rock River is supposed to have discharged to the Illinois. The moraine is so bulky as to completely conceal the course of this valley, whose presence is known only by well borings. It is probable that the drift in places exceeds 600 feet in depth where the moraine occupies this old valley. The sections given below will set forth the basis for this opinion.

With the exception of a narrow strip on the southern border of the county, and the elevated southwestern portion outside the Wisconsin drift sheet, the drift of this county is a very heavy deposit. The average of 29 well sections which reach rock, the majority of which are in the southwest part, show a thickness of 155 feet; but this is evidently much below the average for the county, since 82 records of deep wells which do not reach rock and which are scattered widely over the county are found to average 190 feet in depth. It is probable that the average thickness for the county exceeds 200 feet, and it may possibly reach 300 feet. It is thought that the thickness is greater in this county than in any other within the State.

The upper portion of the drift, to a depth of 100 feet or more, in the portion of the county covered by the Wisconsin sheet is composed in the main of a blue till. The well sections indicate that the lower portion of

the drift contains a larger proportion of sand and gravel than the upper. In the marshy area outside the Wisconsin sheet, which occupies much of the northwest part of the county, there is a surface sand a few feet in depth, but the deep wells usually penetrate a large amount of clay. Sand dunes also cover portions of the elevated moraine. In the southwestern portion of the county the drift is of variable constitution and contains but a small amount of blue till, except where its depth is unusually great.

In the eastern portion of the county numerous instances of the occurrence of a buried soil have been brought to light by the deep wells. In several of the wells which penetrate a buried soil inflammable gas has been obtained, which in some instances has been of sufficient strength to furnish light and fuel for dwellings for a period of several years. Three wells in the village of Lamoille show gas with a pressure of 18 pounds per square inch, another 20 pounds, and still another about 11½ pounds. A dozen or more other wells have a weaker pressure. A well at George Windle's, 2 miles east of Lamoille, has a pressure of 26 pounds per square inch, and one at C. L. Dayton's, 3 miles north of Lamoille, has a pressure of 28 pounds. Many other weaker wells are found between Lamoille and Mendota. The strong wells usually obtain gas in sand and gravel while the weak ones find it in a greenish clay, associated with the buried muck and soil. It seems probable that the gas is formed from the vegetation in these muck beds, though another possible source is found in the escape upward from the underlying Trenton limestone. This limestone in the neighboring States of Indiana and Ohio is found to yield gas in large quantities. The heavy blanket of bowlder clay which occurs in this region forms a suitable barrier to prevent the gas from escaping. A small amount of gas, however, has been noted from the early days of settlement to escape along the borders of Pike Creek in the vicinity of Lamoille.[1]

INDIVIDUAL WELLS.

The public water supply at Princeton is obtained from two wells, 2,093 and 2,525 feet in depth. They apparently each terminate in the Lower Magnesian limestone. The head is about 72 feet below the surface, or 638 feet above tide. The shallower one is cased to a depth of 1,000 feet,

[1] The statistics concerning these gas wells were largely contributed by Miss Ella Lemmon, of the Lamoille public schools, and by Mr. George Dean, of Lamoille.

with inner casing 4⅝ inches in diameter, and has a capacity of 320 gallons per minute. The water is moderately hard and but slightly saline. A partial analysis shows only 3.7 grains per gallon of sodium chloride and 28.5 grains of total solids. A portion of the water is from the St. Peter sandstone at a depth of 1,520 to 1,670 feet, and a portion from the Lower Magnesian at 1,850 to 1,975 feet. The temperature of the water is 64° F. These wells are of exceptional interest since they strike into a deep part of the preglacial valley which, as indicated above, appears to have been the old course of Rock River into the Illinois. A careful record was kept of the shallower well, and the following section of drift is reported by Mr. Jacob Miller, of Princeton:

Section of drift penetrated in a deep well at Princeton.

	Feet.
Clay	47
Sand and gravel	10
Bowlder clay	88
Gravel with inflammable gas	5
Bowlder clay	25
Sand and gravel	197

Beneath the drift 75 feet of shale was penetrated before hard rock was entered. The deeper well, which was sunk several years earlier, is thought to have reached a depth of 440 feet before entering rock, or about the level of the bottom of this shale. Mr. Miller states that its section was not so carefully kept as that of the later well, and it is possible that the drift was no deeper than 372 feet. This gives the rock floor of the valley an altitude 338 feet above tide, or but 50 feet higher than low water of the Mississippi at Cairo, 350 miles nearer the seaboard. A well sunk at Princeton many years ago, and reported by Judge Shaw in the Geology of Illinois, penetrated only 216 feet of drift and was drilled to a depth of but 313 feet.[1] This well is scarcely one-half mile distant from the wells just discussed, yet it seems to have struck the old bluff.

The village of Buda obtains its public water supply from a well 1,610 feet in depth. The lower 140 feet is thought by citizens to be in St. Peter sandstone. The head is 125 feet below the surface or about 640 feet above tide. The well has a diameter of 6 inches and will supply fully 100 gallons per minute, as was shown by a 24-hour test. A strong water vein was struck at 295 feet, but this is cased out. The casing extends into limestone

[1] Geology of Illinois, Vol. V, 1873, pp. 172–173.

only a few feet at a depth of 475 feet. The drift is mainly blue till and is 160 feet in depth. From the base of the drift to 415 feet there is shale and thin beds of sandstone. A bed of coal 4 feet thick was passed through at about 225 feet. The well was mainly in limestone from 415 feet to 1,470 feet, where it is thought that St. Peter sandstone was entered.[1]

An artesian well has been sunk at Bureau Junction, in the Illinois Valley, to a depth of 308 feet. A flow of water was obtained without reaching the bottom of the Coal Measures. The well mouth is but 475 feet above tide, and as 135 feet of drift was penetrated, the rock floor has an altitude only 340 feet above tide, or about the same as at Princeton. A neighboring well on the farm of Mr. Miller, in sec. 30, T. 15, R. 10 E., enters rock at about the same level above tide.

The deepest reliable section of drift reported within the county is that of a well at the village of Ohio, situated near the crest of the moraine in the northern part of the county. This well entered rock at a depth of 412 feet, but as the altitude is 920 feet above tide, the rock floor is 508 feet, or 170 feet higher than in the Princeton well. It is probable, therefore, that the well strikes the bluff of the old valley.

At Neponset, which is situated on the upland outside the Wisconsin drift sheet, in the southwest part of the county, the following complex series of drift deposits was penetrated by a coal shaft:

Section of drift beds penetrated in a coal shaft at Neponset.

	Feet.
Loess	12
Sand	4
Blue clay (Iowan till ?)	10
Peat, with wood embedded	3
Marl of dark color	2
Blue clay	8
Sand	3
Till	18
Sand	3
Yellow till	67
Total drift	130

The altitude at this shaft is about 825 feet above tide. The position of the peat and marl beds in the Pleistocene series is not yet determined, nor is it known whether it is of similar age to the buried soil found within the limits of the Wisconsin drift in this county.

[1] Information furnished by Mr. A. J. Fisher, of Buda.

In the following list of deep wells the majority of sections were collected for the Survey by Prof. J. A. Udden, who has furnished them for publication in this place. It should be noted that where he uses the word "clay" there is usually till, but such is not always the case.

Table of deep wells in Bureau County.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
In T. 18, R. 7 E., at New Bedford School.	660	145	Water from sand at bottom; drift mainly blue clay.
In sec. 34, T. 18, R. 7 E.	670	136	Clay, 100 feet; sand, 36 feet.
W. Meek, sec. 9, T. 18, R. 7 E.	650	110	Mainly blue clay; no rock.
Oscar Wolf, sec. 10, T. 18, R. 7 E	680	200	Clay, with sand at bottom.
A. J. Wiggins, sec. 36, T. 18, R. 7 E.	.800	270	Clay, 130 feet; coarse gravel, 120 feet; dry sand, 60 feet; bowlder clay and sand, 60 feet; no rock.
Mr. Erickson, sec. 36, T. 18, R. 7 E.	675	100	Sand, 10 feet; clay, 30 feet.
In T. 18, R. 8 E., at Bunker Hill School.	835	330	Sand, 40 feet; clay, 140 feet; sand, 2 feet; clay, 123 feet; sand, 15 feet; gas at 210 feet.
W. S. Odell, sec. 5, T. 18, R. 8 E.	680	170	Sand, 20 feet; clay, 145 feet; sand at bottom, 5 feet.
W. C. Stearns, sec. 9, T. 18, R. 8 E.	750	303	Bowlders in upper 50 feet; clay to 200 feet; sand, a few feet: clay at bottom.
Near Walnut, in sec. 9, T. 18, R. 8 E.	780	260	Yellow till, 13 feet; sand, 3 feet; till, 60 feet; blue till, 20 feet; sand, 2 feet; hard till, 15 feet; sand, 1 foot; blue till, 141 feet; sand, 5 feet; no rock struck.
Mr. Waterhouse, sec. 15, T. 18, R. 8 E.	815	280	Sand and clay, 165 feet; gravel, 5 feet; clay, 100 feet. Sand at bottom. Gas at 190 feet.
Mr. Rumberger, sec. 30, T. 18, R. 8 E.	810	317	Sand, 100 feet; then clay to bottom.
Mr. Milliken, sec. 35, T. 18, R. 8 E.	830	195	Sand, 40 feet; gravel, 5 feet; remainder, clay.
Mr. Catterman, sec. 36, T. 18, R. 8 E.	800	260	Clay, 250 feet; sand at bottom.
Walnut Cheese Factory	710	200	Blue clay, 60 feet; sand, 10 feet; reddish clay, 80 feet; gravel, 3 feet; fine sand at bottom.
Ohio, village well	920	412	Clay, 150 feet; sand with gas, 50 feet; clay, 40 feet; sandy blue bowlder clay to limestone at bottom.
J. Joder, near Ohio, in sec. 8.	890	390	Not certain to have struck rock.
G. Windle, sec. 21, T. 18, R. 11 E.	800	242	Sand, 6 feet; reddish clay, 51 feet; sand, 14 feet; reddish clay, 18 feet; gravel with gas, 14 feet; peaty soil with timber, 18 feet; sand, 8 feet; gravel at bottom, 17 feet.

Table of deep wells in Bureau County—Continued.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
W. Morris, sec. 31. T. 18, R. 11 E.	780	265	Clay, 100 feet; dry sand, 12 feet; clay, 40 feet; cemented gravel, 103 feet (possibly hard till).
W. Thomas, sec. 5, T. 17, R. 6 E.	640	98	No rock struck.
Robert Smith, sec. 16, T. 17, R. 6 E.	630	108	Sand, 40 feet; blue clay, 60 feet; sand at bottom.
G. Pittmans, sec. 2, T. 17, R. 7 E.	690	200	No rock struck.
Mr. McKuen, sec. 3, T. 17, R. 7 E.	720	180	Mainly clay; no rock.
Mr. McKuen, sec. 10, T. 17, R. 7 E.	710	208	Mainly clay; no rock.
Mr. Siebel, sec. 8, T. 17, R. 7 E.	690	160	No rock struck.
Mr. White, sec. 13, T. 17, R. 7 E.	750	220	No rock; mainly bowlder clay.
H. Sayers, sec. 14, T. 17, R. 7 E.	750	250	No rock struck.
L. Miller, sec. 15, T. 17, R. 7 E.	680	200	No rock struck.
D. A. Miller, sec. 15, T. 17, R. 7 E.	710	250	No rock struck.
J. P. Follet, sec. 16, T. 17, R. 7 E.	710	250	Clay, 230 feet; sand at bottom; wood at 60 feet.
W. J. McKey, sec. 18, T. 17, R. 7 E.	675	140	Bowldery till; no rock.
D. Weinck, sec. 18, T. 17, R. 7 E.	675	140	Sand, 20 feet; blue clay, 100 feet; fine blue sand at bottom.
A. Nelson, sec. 21, T. 17, R. 7 E.	670	217	No rock; clay, 180 feet.
O. Smith, sec. 22, T. 17, R. 7 E.	750	272	No rock struck.
C. Samuelson, sec. 24, T. 17, R. 7 E.	810	323	Sand, 20 feet; clay, 125 feet; "hardpan," 130 feet; clay and sand to bottom, 148 feet.
C. Beachler, sec. 9, T. 17, R. 8 E.	810	270	Clay, 125 feet; sand and gravel with "black stuff" embedded, 145 feet.
P. Erisman, sec. 10, T. 17, R. 8 E.	750	288	No rock struck.
J. Carr, sec. 11, T. 17, R. 8 E.	750	265	Mainly clay; no rock.
Mr. Knaus, sec. 13, T. 17, R. 8 E.	700	317	No rock struck.
J. Springer, sec. 25, T. 17, R. 8 E.	700	200	No rock; wood in clay at 160 feet.
J. Gillam, sec. 6, T. 17, R. 9 E.	750	210	No rock struck.
R. Beatty, sec. 7, T. 17, R. 9 E.	725	200	Clay, 120 feet; gravel with gas, 20 feet; clay, 60 feet. Sand at bottom.
Mr. Taylor, sec. 13, T. 17, R. 9 E.	740	165	Clay, 160 feet. Sand with gas at bottom.
S. Clark, sec. 24, T. 17, R. 9 E.	720	277	Clay, 100 feet; gravel with gas, 17 feet; clay, 40 feet; bowlder clay, 13 feet; gummy clay, 35 feet; sandy hardpan to bottom, 70 feet.
A. Dunbar, sec. 26, T. 17, R. 9 E.	730	180	Clay, 160 feet. Black sand at bottom.
J. Allen, sec. 35, T. 17, R. 9 E.	720	145	Gas in clay at bottom.
J. Henzell, sec. 30, T. 17, R. 10 E.	720	175	In Coal Measures rock, 20 feet, at bottom.
Lamoille Shoe Factory	800	118	Gas in dry sand at bottom.
Lamoille Mills	800	118	Gas in dry sand at bottom.
Mrs. Booth, in Lamoille	800	130	Gas in dry sand at bottom.

Table of deep wells in Bureau County—Continued.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
E. Stevenson, in Lamoille	800	150	Gas well; no rock.
L. Hopps, near Lamoille	800	130	Gas in sand at bottom.
C. L. Dayton, near Lamoille	800	207	Gas and water in sand at bottom.
Mr. Perkins, sec. 5, T.17, R.11 E	750	147	Yellow till, 14 feet; blue till, 117 feet; hard gray till, 15 feet. Sand with gas at bottom.
A. Searle, sec. 32, T. 16, R. 10 E	650	265	No rock struck; mainly sand.
M. Frey, sec. 22, T. 16, R. 10 E	680	120	No rock; mainly sand.
One-half mile north of Depue	490	50	Entirely sand.
N. Anderson, sec. 30	520	300	Enters rock at about 100 feet.
Mr. Seaton, sec. 9	700	100	Enters rock near bottom.
Seaton and vicinity	625	45	Drift about 45 or 50 feet.
Near Hollowayville	700	80	Mainly till; sand at bottom.
Ladd, coal boring	656	175	Rock entered at 175 feet.
Princeton artesian well	700	372	Rock entered at 372 feet.
Princeton, old artesian well	700	313	Rock entered at 216 feet.
Mr. Rickmeyer, 3 miles northeast of Princeton.	670	272	Clay, 90 feet; gravel and sand, 182 feet.
A. T. Weise, sec.36, T.16, R.9 E.	485	395	Rock entered at 160 feet.
Sec. 20, T. 16, R. 9 E	700	260	No rock struck.
In T. 16, R. 8 E., at Mr. Kaufmann's, sec. 13.	690	260	Clay, 125 feet. Sand and clay to bottom.
Company's well, sec. 16, T. 16, R. 8 E.	600	120	Sand, 40 feet; blue till, 80 feet. Sand at bottom.
J. Sapp, sec. 18, T. 16, R. 8 E.	645	172	No rock. Gas in sand at 85 feet.
L. L. Lay, sec. 31, T. 16, R. 8 E.	770	130	No rock. Gas in old soil.
J. Pottorf, sec. 32, T. 16, R. 8 E.	720	287	Rock? at bottom.
S. W. ¼ sec. 32, T. 16, R. 8 E	700	80	Sandstone entered at 80 feet.
C. Hays, at Wyanet	660	140	Clay, 40 feet; sand, 10 feet; blue clay, 25 feet; clay with sand veins to bottom, 50 feet.
Wyanet prospect boring	660	112	Rock entered at 112 feet.
Lovejoy coal shaft	700	62	Yellow till, 20 feet; sand, 12 feet; blue till, 30 feet. Sandstone above coal.
County farm, east of Wyanet	600	160	Not certain whether rock was struck.
J. B. Stewart, near Wyanet	700	150	Mainly till. Wood and sand at bottom.
Buda, village well	760	120	Till, 70 feet; sand, 10 feet. Till with thin sand beds to bottom. Artesian well recently sunk has 160 feet of drift.
Mrs. Mammon, in Buda	780	232	Till, 85 feet. Remainder mainly sand.
E. Harbrook, sec. 8, T. 16, R. 7 E	670	150	Clay, 75 feet. Fine blue sand to bottom.
Nels Olson, sec. 12, T. 16, R. 7 E.	750	220	Mainly clay; lower 50 feet sand.
Sheffield and vicinity	675	10	Rock entered at 10 to 20 feet.
Mineral, railway well	638	60	In blue clay at bottom.

Table of deep wells in Bureau County—Continued.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
A. Stevens, sec. 1, T. 15, R. 7 E..	750	200	Enters rock at 150 feet.
D. Brady, sec. 23, T. 15, R. 7 E..	800	200	Enters rock at 150 feet.
In T. 15, R. 8 E., at G. Kitterman's, sec. 1.	540	90	Entirely sand.
Frank Stevens, sec. 14, T. 15, R. 8 E.	720	116	Enters rock at 116 feet.
Mr. Whiting, sec. 14, T. 15, R. 8 E	700	100	Enters rock at 100 feet.
A. Greenman, sec. 20, T. 15, R. 9 E.	650	212	Blue clay, 110 feet; sand, 102 feet.
H. Benson, sec. 21, T. 15, R. 9 E.	640	300	Clay, 120 feet. Remainder sand.
Bureau Junction	475	308	Drift, 135 feet.
S. Russell, sec. 5, T. 15, R. 10 E .	600	196	No rock struck.
C. Averill, sec. 7, T. 15, R. 10 E .	500	130	Entirely sand.
J. Rudberg, sec. 8, T. 15, R. 10 E	600	245	No rock; mainly sand.
Mr. Miller, sec. 30, T. 15, R. 10 E	445	260	Drift about 100 feet.

PUTNAM COUNTY.

GENERAL STATEMENT.

Putnam County is situated southeast of Bureau, immediately south of the great bend of the Illinois, and is traversed in a southward course by that stream. It is one of the smallest counties in the State, its area being but 170 square miles, and Hennepin is its county seat. The county is situated mainly east of the Illinois River, there being scarcely 50 square miles on the west side of the stream. The valley of the Illinois River in this county has a width of about 5 miles. The remainder of the county is an upland standing 200 to 300 feet above the level of the river. The most elevated part is on the eastern border near Mount Palatine, where an altitude of 725 to 750 feet is attained.

Throughout the county there is a heavy deposit of drift, averaging fully 150 feet in thickness. The upper portion on the uplands to a depth of 75 or 100 feet is mainly bowlder clay, but the lower portion, and nearly all the drift in the valley of the Illinois, is sand and gravel. The list of deep wells presented below was furnished by Prof. J. A. Udden, with the exception of the artesian well at Hennepin, data concerning which were furnished by A. T. Purviance, county clerk.

INDIVIDUAL WELLS.

The Hennepin artesian well is 800 feet in depth and has a head sufficient to carry the water at least 50 feet above the surface. It has a discharge of 80 gallons per minute from a 4-inch pipe. There is a slight salinity, but the water is not unpleasant to the taste. The well is cased nearly to the bottom and the water has a temperature of 58° F. The drift is about 150 feet in thickness. The altitude of the well being scarcely 500 feet, the rock floor is but 350 feet above tide, or nearly as low as at the wells in Princeton and Bureau Junction.

The Putnam City artesian well obtains water from the Coal Measures, but the depth was not ascertained. It penetrated about 200 feet of drift, and entered rock at a level slightly below 350 feet above tide.

Table of wells in Putnam County, by Prof. J. A. Udden.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Mr. Wheeler, near Putnam City.	470	107	Clay, 12 feet; sand, 35 feet; blue clay, 60 feet; sandstone at bottom.
C. Reed, sec. 25, T. 14, R. 9 E ...	620	231	Clay, 16 feet; gravel, 12 feet; gray clay, 85 feet; sand and gravel, 108 feet; Coal Measures at bottom.
F. Willmann, sec. 33, T. 33, R. 1 W.	670	280	Clay, 75 feet; sand, 9 feet; reddish clay, 19 feet; sand, 5 feet; red clay, 15 feet; sand, 45 feet; alternations of clay and sand to bottom; no rock.
Granville creamery............	670	135	Blue till, 30 feet; reddish clay, 50 feet; sand and gravel, 48 feet; rock, 7 feet.
W. Sill, sec. 17, T. 32, R. 1 W ...	710	114	No rock struck.
J. Henning, sec. 22, T. 32, R. 1 W.	730	182	Yellow clay, 12 feet; blue clay, 80 feet; "hardpan," 90 feet; rock near bottom.
Sec. 11, T. 32, R. 2 W	580	200	Rock entered at 155 feet; drift mainly sand and gravel.
Sec. 14, T. 32, R. 2 W	600	226	No rock struck; mainly bowlder clay.
Sec. 5, T. 31, R. 1 W	690	280	Bottom in sand.
Sec. 6, T. 31, R. 1 W	690	100	Bottom in sand.
J. Mills, sec. 11, T. 31, R. 1 W...	710	160	Rock entered near bottom.
J. Kays, sec. 30, T. 31, R. 1 W...	660	240	Mainly till; gravel at bottom.
W. Glenn, sec. 31, T. 31, R. 1 W.	670	160	In clay at bottom.
Mount Palatine	730	150	Mainly till; no rock struck.

LASALLE COUNTY.

GENERAL STATEMENT.

Lasalle County is situated in the north-central part of the State, immediately east of Bureau and Putnam counties and above the bend of the Illinois River. That river traverses the county nearly central from east to west. It is the second county in size, being exceeded only by McLean County, and has an area of 1,152 square miles. Ottawa, the county seat, is situated near its geographic center, at the junction of Fox River with the Illinois. Fox River traverses the northeastern portion in a southwestward course and receives the drainage of much of the northern half of the county. Vermilion River traverses the southern portion of the county in a northwestward course, entering the Illinois opposite the city of Lasalle and dividing the portion south of the Illinois into nearly equal parts. The Little Vermilion drains the northwest portion of the county in a southward course and enters the Illinois at Lasalle.

The most elevated portion of the county is in the northwest corner, which is occupied by the inner portion of the Bloomington morainic system. The altitude here reaches about 900 feet above tide. Much of the uplands in the county stand below 700 feet. The extreme southwestern portion, however, rises to about 750 feet, and the Marseilles moraine on the eastern border of the county has a crest line about 750 feet above tide. The greater portion of the surface is nearly plane. There is, however, aside from the two moraines just mentioned, a small morainic belt (Farm Ridge) which occupies the upland immediately east of Little and Big Vermilion rivers, crossing the Illinois River between Utica and Lasalle.

The principal streams of the county have excavated valleys in the rock, and wells on the uplands frequently enter rock at depths of 50 feet or less, except in the elevated portions referred to in the northwest, southwest, and east parts of the county. In the northwest part the thickness of the drift exceeds 200 feet. In the southwest part it is apparently about 150 feet. In the eastern part, along the Marseilles moraine, it is 200 feet or more. The average distance to rock in 55 of the deep wells on the upland and 8 deep wells in the valleys is 99 feet. Records were obtained of 85 other deep wells which do not enter rock, though their average depth is 89 feet. They are largely situated on the Marseilles moraine. The wells entering rock

here discussed are distributed with some uniformity over the entire county, except the portion southwest of Vermilion River, where very few records have been obtained.

The upper portion of the drift, and indeed the deposit penetrated by nearly the entire depth of the wells throughout the county, is blue till. There are, however, small areas in which the drift contains a larger amount of sand and gravel than till, and thin beds of gravel or sand appear to be quite generally present in the till. These afford water for the shallow wells on the farms and in villages. The public wells in cities and villages and the stock wells on the farms are usually sunk to considerable depth.

On the north border of the county, near Earlville, many flowing wells have been obtained from the drift, usually at depths of 25 to 50 feet, or even less, but occasionally of greater depth. Strong hydrostatic pressure is exhibited by wells situated on the lower portion of the slopes of the large moraines in the northwestern and in the eastern part of the county. This pressure is in all probability due to absorption of the water on more elevated portions of the moraine. The flowing well district near Earlville is thus related to the moraine on the northwest. A few other flowing wells occur in the county in valleys or lowland tracts, which are probably supplied from the neighboring higher land.

Many artesian wells are obtained from the St. Peter sandstone, Lower Magnesian limestones and sandstone, and the Potsdam sandstone along the borders of the Illinois River, and occasionally at points on the uplands, as appears in the discussion below.

INDIVIDUAL WELLS.

The city of Mendota, in the northwest part of the county, obtains its public water supply from wells about 400 feet in depth sunk to the St. Peter sandstone. A portion of the water may be derived from higher horizons. The head is sufficient to bring the water within 40 feet of the surface, or to about 710 feet above tide, which is somewhat higher than the head for the St. Peter in this region. The private wells at Mendota are usually obtained at depths of but 12 to 20 feet in beds of sand or gravel between the yellow and blue tills. A few deep wells have been sunk in the vicinity of the city, which show the drift to be 160 to 200 feet in depth. An old soil is frequently passed through in the lower part of the drift at a depth of 100 feet or more. The till above the soil is usually of a blue

color and comparatively soft, being apparently of Wisconsin age. That below the soil is of a brown or gray color and usually is rather hard. Several gas wells have been obtained near the level of this old soil, as in the neighboring portion of Bureau County, discussed above. Here, as in Bureau County, the gas is probably largely derived from decomposition of the vegetation in the buried soils and in the drift, but a portion may be derived by escape from the underlying Trenton limestone.

At Earlville, near the north border of the county, the public water supply is from an 8-inch tubular well 150 feet in depth, which terminates in limestone. The private wells in that vicinity are 30 to 60 feet in depth and usually obtain water in gravel below till, though a few enter the rock.[1]

The public water supply at the city of Peru is obtained from an artesian well 1,250 feet in depth, which terminates probably above the St. Peter sandstone. Another well at the zinc works in Peru, 1,360 feet in depth, obtains its supply from the St. Peter at the bottom and probably in part from the limestones above this sandstone. The waterworks well is estimated to have a capacity of 450 gallons per minute and its head is sufficient to cause an overflow at 85 feet above the well mouth or 560 feet above tide. An analysis of the water has been published in the Seventeenth Annual Report of this Survey.[2] This analysis shows but 16 grains of sodium chloride per gallon and the water is considered of excellent quality. There is about 130 feet of drift in the Illinois Valley at this point. This gives the rock floor an altitude but 330 feet above tide, which is fully as low as at wells in this valley in Bureau and Putnam counties. This city seems to stand a few miles east from the main preglacial valley.

The city of Lasalle obtains its public water supply in part from springs and in part from two artesian wells obtained in the Coal Measures sandstone at depths of 332 and 530 feet. The springs yield about 1,500,000 gallons a day and the wells about one-third that amount (C. H. Nicolet, city engineer.) Many private wells are obtained in Lasalle at depths of 10 to 30 feet in gravel near the base of the drift. The Illinois River from Lasalle eastward being outside the line of the preglacial valley, which it enters west of this city, rock is found at comparatively slight depths in the valley bottom.

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[1] The flowing wells near Earlville are discussed in the Seventeenth Annual Report of this Survey (Part II, pp. 779–780).

[2] Part II, p. 828.

At the village of Utica many artesian wells have been obtained in the Lower Magnesian limestone. The strongest wells are obtained at depths of 215 to 330 feet, but many are of much less depth. The water rises to a height of about 50 feet above the surface, or 525 feet above tide. The strongest wells have an estimated capacity of about 150 gallons a minute, or 200,000 gallons a day.

The city of Ottawa formerly obtained much of its public water supply from shallow wells piped to a reservoir on the south bluff of the river and distributed by gravity to the city. It is now supplied from six artesian wells and Fox River. A large number of private artesian wells are sunk through the St. Peter sandstone to the underlying strata, from which an excellent quality of water overflows. It is estimated that there are not less than 200 such wells in the city and vicinity. The great majority are but 300 to 400 feet in depth. One boring was sunk, however, to a depth of 1,840 feet and obtained water from the Potsdam, which has a strong flow in the lower 200 feet. The head is estimated to reach 175 feet above the well mouth, or 705 feet above tide The quality of the water is variable in the several wells, but is usually slightly sulphurous and moderately hard. The salinity is very slight.

At the village of Marseilles a large number of private artesian wells have been sunk which obtain water from the St. Peter sandstone at depths of 100 to 200 feet. The head is remarkably low, being but 12 to 20 feet above the surface, or scarcely 500 feet above tide. The wells are ordinarily but 2 inches in diameter, with a nozzle 1 inch in diameter. Their rate of flow has appreciably decreased within the past 15 years and at present an average well will discharge but 4 or 5 gallons a minute. For fire purposes the village has a system of waterworks which pumps its supply from the Illinois River.

The village of Seneca, situated in the Illinois Valley near the east border of the county, is also supplied with several private artesian wells, which obtain water from the St. Peter or lower strata at depths ranging from 350 to 680 feet. The strongest flow is thought to be obtained at a depth of about 630 feet. The water is slightly sulphurous, but is otherwise of pleasant taste. The head, like that of the wells at Marseilles, is remarkably low, being scarcely more than 20 feet above the surface at the wells, or 525 feet above tide.

Streator, a city located on the southern border of the county, obtains its public supply by pumping from Vermilion River. Many private wells are obtained at depths of 20 to 40 feet, from gravel in the drift. An artesian well was sunk in this city to a depth of 2,496 feet, terminating in the Potsdam sandstone. Water was struck in the St. Peter sandstone at 450 feet, which has a head 578 feet above tide, or 40 feet below the surface. In the Lower Magnesian strata the head was increased a few feet, and in the Potsdam, at 2,170 to 2,496 feet, water was struck which has a head 45 feet above the surface, or 663 feet above tide. A section of this well and also of the deepest well at Ottawa has been published in the Seventeenth Annual Report of this Survey.[1]

At Vermilionville, in the valley of Vermilion River, a few miles below Streator, a boring made for oil reached a depth of 1,000 feet and obtained a strong flow of excellent water. Numerous springs occur along the Vermilion River below Streator, which are in part from the St. Peter and in part from Coal Measures. The water is usually of excellent quality.

An artesian well 2,189 feet in depth was made by Mr. Pedicord on the uplands north of the Illinois River near Marseilles, at an altitude about 700 feet above tide. When cased, an overflow from a depth of 1,850 feet was obtained. The well penetrated 169 feet of glacial drift.[2]

The following table of deep wells along the Marseilles moraine begins in the northeast part of the county and proceeds southward. The moraine is situated immediately east of Fox River as far south as the mouth of that stream. Upon crossing the Illinois it bears east of south, leaving the county near the southeast corner. The width, including the slopes, is 5 or 6 miles.

Wells along the Marseilles moraine in eastern Lasalle County.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Sec. 23, T. 35, R. 5 E	675	137	St. Peter sandstone at 130 feet; drift mainly blue till.
Sec. 23, T. 35, R. 5 E	650	100	Three wells about 100 feet, with no rock.
Sec. 33, T. 35, R. 5 E	700	153	St. Peter sandstone at bottom; drift mainly blue till.
Sec. 4, T. 34, R. 5 E	720	233	Till, 138 feet; sand and gravel, 13 feet; blue clay, 17 feet; St. Peter sandstone, 65 feet.
Sec. 5, T. 34, R. 5 E	650	105	Strikes rock at bottom.

[1] Part II, pp. 798–799.

[2] Geol. of Illinois, Vol. VII, p. 50.

Wells along the Marseilles moraine in eastern Lasalle County—Continued.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Sec. 5, T. 34, R. 5 E	675	160	Till, 100 feet; sand, 10 or 15 feet; clay, 10 or 15 feet; Coal Measures shale, etc., 35 feet; St. Peter sandstone near bottom.
Sec. 9, T. 34, R. 5 E	700	196	St. Peter sandstone near bottom; hard brown till below blue till at 166 feet.
Sec. 6, T. 34, R. 5 E	650	100	Mainly sand and gravel; no rock.
Sec. 9, T. 34, R. 5 E	675	210	No rock struck.
Sec. 16, T. 34, R. 5 E	700	200	St. Peter (?) sandstone entered near bottom below drift.
Sec. 18, T. 34, R. 5 E	700	200	In gravel at bottom.
Sec. 27, T. 34, R. 5 E	650	160	St. Peter (?) sandstone at bottom.
Sec. 22, T. 34, R. 5 E	700	185	No rock struck.
Sec. 24, T. 34, R. 5 E	650	100	Coal Measures sandstone at bottom.
Sec. 28, T. 34, R. 5 E	700	180	Mainly till; hard rock at bottom.
Sec. 11, T. 34, R. 4 E	650	195	Till, 93 feet; gravel, 7 feet; "potter's clay," 40 feet; sandstone, 55 feet; St. Peter sandstone near bottom.
Sec. 14, T. 34, R. 4 E	650	100	In sand below till.
Danway and vicinity	690	100	Several wells 100 feet deep do not enter rock; mainly through till.
Sec. 13, T. 34, R. 4 E	675	107	Three wells, 100 to 107 feet; mainly through till; no rock.
Sec. 23, T. 34, R. 4 E	650	118	Yellow till, 15 feet; blue till, 75 feet; black clay or soil, 8 feet; sand, 20 feet; no rock.
Sec. 34, T. 34, R. 4 E	620	68	Soft till, 28 feet; hard, dry till, 40 feet; rock at bottom.
Sec. 35, T. 34, R. 4 E	650	85	No rock; mainly blue till.
Secs. 3 and 4, T. 33, R. 5 E	650	....	Molluscan shells in sand at 6 to 10 feet; wells, 10 to 33 feet.
A. Irwin, bluff north of Seneca	610	108	No rock; mainly till.
Sec. 20, T. 33, R. 4 E	630	215	Drift, 40 feet; St. Peter sandstone at 215 feet.
Sec. 26, T. 33, R. 4 E	740	219	Till, 170 feet; sand and till to bottom.
Sec. 26, T. 33, R. 4 E	720	252	Till, 198 feet; gray, sandy clay, 38 feet; sandstone, 14 feet; shale, 2 feet.
Bluff south of Marseilles	675	184	Till, 165 feet; sand and gravel to bottom.
Sec. 36, T. 33, R. 4 E	700	177	Till, 170 feet; sand at bottom.
Sec. 21, T. 33, R. 5 E	675	80	Yellow clay, 10 feet; gravel, 70 feet.
Sec. 1, T. 32, R. 4 E	740	232	Till, 150 feet; remainder sand and till.
Sec. 2, T. 32, R. 4 E	725	220	Till, 150 feet; remainder sand and till.
Sec. 2, T. 32, R. 4 E	725	194	Till, 116 feet; sand and till to bottom.
Sec. 35, T. 32, R. 4 E	700	108	Entirely through till.
Sec. 29, T. 32, R. 5 E	700	130	Entirely through till.
Sec. 30, T. 32, R. 5 E	700	128	Till, 125 feet; sand at bottom.

Wells along the Marseilles moraine in eastern Lasalle County—Continued.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Sec. 9, T. 31, R. 5 E	720	181	Rock? at bottom.
Sec. 14, T. 31, R. 5 E	690	103	Mainly till; rock at bottom.
Mr. Cate, near Ransom	720	543	Drift, mainly till, 285 feet; Coal Measures and limestone (Trenton?) extending to St. Peter sandstone at 510 feet.
S. Cleals, near Ransom	720	370	Drift, mainly till, 270 feet; Coal Measures, 100 feet; limestone (Trenton?) near bottom.
Sec. 5, T. 31, R. 5 E	720	144	Mainly till; sand at bottom.
Sec. 35, T. 31, R. 5 E	700	130	Enters rock near bottom.
Sec. 36, T. 31, R. 5 E	675	160	Enters rock at 120 feet.
Sec. 27, T. 31, R. 5 E	700	175	Gas well from drift sand; water stands 6 feet below surface.
Sec. 36, T. 31, R. 4 E.; also secs. 25 and 26.	700	160	Several wells about 160 feet; none enter rock.

The following table includes the deepest well sections obtained in other parts of the county aside from the artesian wells discussed above:[1]

Wells of Lasalle County outside the Marseilles moraine.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet	*Feet.*	
Sec. 11, T. 36, R. 5 E	650	80	Five wells enter first rock at about 20 feet and St. Peter sandstone at 35 or 40 feet.
Sec. 11, T. 36, R. 5 E	650	20	Black muck with wood and leaves below till at bottom.
Sec. 9, T. 36, R. 3 E	700	180	Boring for coal struck old soil at 35 to 40 feet and entered rock at 50 feet.
Sec. 9, T. 36, R. 3 E	680	20	Two flowing wells in Indian Creek Valley.
T. 36, Rs. 2 and 3 E	690	....	Thirty flowing wells 18 to 85 feet in depth from sand below till.
D. Knight, sec. 34, T. 36, R. 4 E.	675	80	Enters rock at 63 feet; well half mile west enters rock at 63 feet.
NW. part of T. 36, R. 1 E	850	200	Several wells 150 to 200 feet, with no rock.
1½ miles north of Mendota	800	198	Gas at 75 and 128 feet; old soil at 178 feet; water rises 90 feet from gravel at bottom.
Mr. Miller, near Mendota	725	144	Flowing well from gravel below till; a buried soil from 120 to 125 feet.

[1] For sections of several wells in the vicinity of Mendota the writer is indebted to Mr. L. R. Curtis of that city.

Wells of Lasalle County outside the Marseilles moraine—Continued.

Owner or location.	Altitude. (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Porterfield's gas wells near Mendota.	700 to 725	176	Five wells 120 to 176 feet; deepest reaches rock; black muck or soil with leached subsoil between till sheets at about 600 feet above tide; gas in sand above old soil.
Blanchard's gas well, near Mendota.	750	218	Yellow till, 10 feet; blue till, 56 feet; sand with gas, 96 feet; Trenton limestone, 56 feet.
Sec. 26, T. 35, R. 1 E	610	46	Trenton limestone at 46 feet.
Mr. Finfsen, 6 miles S. from Mendota.	700	143	Well enters Coal Measures shale below drift at 143 feet.
Sec. 32, T. 35, R. 1 E	650	40	Gas from gravel below till.
Sec. 26, T. 35, R. 2 E	700	121	Three wells of similar depth and structure: yellow till, 16 feet; blue till, 85 feet; gravel, 20 feet.
Sec. 23, T. 35, R. 2 E	660	63	Rock at bottom.
Sec. 32, T. 35, R. 2 E	675	54	No rock; mainly till.
Sec. 35, T. 35, R. 2 E	700	98	Rock at bottom; mainly till. Two wells.
Sec. 34, T. 35, R. 2 E	675	76	No rock; mainly blue till.
Sec. 5, T. 34, R. 2 E	700	80	No rock; mainly blue till.
Sec. 4, T. 34, R. 2 E	700	91	Entirely till.
J. Bowen, near Serena	600	104	Till, 40 feet; sand and gravel, 64 feet.
H. Bowen, near Serena	600	75	Enters sandstone at bottom.
Serena and vicinity	635	100	Mainly blue till, 50 or 60 feet; sand and gravel, 15 or 20 feet; St. Peter sandstone at 75 or 100 feet.
Sheridan Junction	641	40	Mainly till; no rock.
Sheridan	591	16	St. Peter sandstone at 12 to 16 feet.
Sec. 27, T. 33, R. 2 E	620	100	No rock; mainly till.
Sec. 33, T. 33, R. 2 E	620	100	No rock; mainly till.
Sec. 23, T. 33, R. 5 E	600	88	Very hard red till near bottom under soft blue till.
Sec. 5, T. 33, R. 2 E	650	47	No rock; mainly till.
Sec. 28, T. 33, R. 2 E	625	50	Rock at 50 feet.
Mr. Kistler, S. Ottawa	585	30	Gravel, 30 feet; till at bottom.
Ottawa waterworks	600	27	Mainly gravel and sand; no rock.
Grand Ridge Station	663	153	Till, 120 feet; sand and gravel to bottom.
Sec. 21, T. 32, R. 3 E	650	200	Till, 140 feet; sand and gravel, 60 feet.
Farm Ridge	680	50	Mainly sand; no rock.
R. Williams, 9 miles north of Streator.	650	140	No rock; blue clay with some sand.
One mile from preceding	650	187	Water rises 87 feet.
One mile from preceding	650	315	St. Peter sandstone at bottom; water brackish.
Sec. 17, T. 32, R. 1 E	675	150	Till about 50 feet; sand about 100 feet; rock at bottom.
Sec. 18, T. 31, R. 4 E	610	65	Mainly sand and gravel; shale at bottom.
Sec. 34, T. 31, R. 4 E	660	100	No rock; entirely till.

KENDALL COUNTY.

GENERAL STATEMENT.

Kendall is a small county, with an area of but 330 square miles, situated east of the northern part of Lasalle and the southern part of Dekalb County, with Yorkville as the county seat. Fox River crosses its northwestern portion in a southwestward course, and nearly half the county is tributary to it. The remainder of the county drains southeastward directly to the Illinois River through Aux Sable Creek and smaller streams.

The Marseilles moraine traverses this county centrally from northeast to southwest, following the southeast border of Fox River Valley, or rather Fox River Valley follows the outer border of this moraine, the course of the stream being determined by the moraine. The remainder of the county has a plane surface, except the east border, which is occupied by the Minooka till ridge. The drift is of moderate thickness, averaging probably 100 feet. A small area in the southern part is very thinly coated and there are numerous rock outcrops along the Fox River Valley. The heaviest drift, apparently, is along the line of the Marseilles moraine, where, as shown in the table below, the thickness usually exceeds 150 feet.

An extensive gravelly area occupies townships bordering Fox River. The gravel extends usually as deep as wells have penetrated, and may continue to the underlying rock. The remainder of the county outside the moraine apparently has much sand and gravel in the lower part of the drift. The Marseilles moraine and the plain to the southeast are characterized by a heavy sheet of till, though there are limited areas in which wells penetrate a large amount of sand or gravel. The Minooka Ridge, also, is composed largely of till. Wells are ordinarily obtained in this county at depths of 25 to 35 feet. The deeper ones are largely found along the Marseilles and Minooka ridges.

INDIVIDUAL WELLS.

At Plano, in the northwest part of the county, several wells reach a depth of 45 feet without entering rock, and are mainly through sand and gravel. The public water supply is from a well.[1] North of this village for 2 or 3 miles wells usually penetrate about 20 feet of till and then enter sand and gravel, in which they terminate at depths of 40 or 50 feet. One

[1] Manual of American Waterworks, 1897.

well, however, in sec. 11, was sunk to a depth of 196 feet and entered rock at about 150 feet. Mr. Otis Latham made a well in Plano which struck an old soil containing grass leaves beneath till at a depth of about 25 feet. Southwest of Plano, in secs. 29 and 31, two wells 44 and 69 feet in depth are mainly through sand, and do not enter rock.

At Oswego there is a very thin coating of gravelly drift on the rock, and wells are usually sunk into the limestone about to the level of Fox River, 30 or 40 feet. The public water supply is from drilled wells.[1] For about 5 miles below Oswego there is a gravel plain on the east side of Fox River a mile or more in width, on which wells are obtained at depths of 10 to 30 feet without entering rock.

At Yorkville the public water supply is obtained from springs in the Marseilles moraine which borders the town on the southeast. The private wells are obtained at depths of 15 to 30 feet and seldom enter the rock.

At Millington flowing wells may be obtained from the St. Peter sandstone at slight depth. Two at the residence of Dr. J. A. Freeman, 78 feet in depth, enter this sandstone 27 feet. The drift, with the exception of about 20 feet of gravel at surface, is mainly till. The wells are ordinarily obtained in this village at depths of 12 to 20 feet in the gravel of the Fox River Valley.

In the vicinity of the village of Plattville on the plain east of the Marseilles moraine many flowing wells have been obtained. The majority have a depth of but 30 to 45 feet, but occasionally a depth of 70 feet or more is reached. The water is obtained in sand below till and the absorbing area is, in all probability, in the Marseilles moraine on the west. A deep well 2 miles north of Plattville at an altitude about 50 feet above the village, or 650 feet above tide, reached a depth of 550 feet and entered St. Peter sandstone at 511 feet. A large amount of water is obtained, but it does not overflow. Rock was entered at 143 feet and is mainly limestone down to the St. Peter sandstone. A well 1½ miles east of Plattville at about the same elevation (600 feet) entered rock at 40 feet and was drilled to a depth of 80 feet.

In the vicinity of Lisbon, where the altitude is 625 to 640 feet, limestone is entered at a depth of 10 feet or less, and wells are obtained at depths of only 30 to 50 feet. For 4 or 5 miles northeast of Lisbon rock is usually

[1] Manual of American Waterworks, 1897.

entered at less than 50 feet, but occasionally a well reaches a depth of 90 feet without entering it. Three wells in secs. 11 and 12, T. 35, R. 7 E., are 48, 50, and 90 feet in depth without reaching rock, and the water has a head nearly level with the surface. The altitude is about 40 feet lower than at Lisbon, or 600 feet above tide.

The following list of wells along the Marseilles moraine include the deepest of which records were obtained. Many shallower wells occur which obtain water at depths of 30 to 40 feet or less. The sections are taken in order, beginning at the northeast corner of the county and passing southwestward:

Wells on the Marseilles moraine in Kendall County.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Sec. 24, T. 37, R. 8 E	700	200	Enters rock at about 200 feet.
Sec. 24, T. 37, R. 8 E	750	152	Yellow till, 18 feet; blue till, 108 feet; sand with clay streaks, 24 feet; gravel at bottom.
Mr. Miner, 4 miles southeast of Oswego.	700	121	No rock; till 100, sand, 21 feet.
Secs. 31 and 32, T. 37, R. 8 E	700	100	Several wells; mainly till; no rock.
Sec. 5, T. 36, R. 8 E	725	150	Enters rock at about 100 feet.
Secs. 22 and 28, T. 36, R. 6 E	675	120	Several wells; mainly blue till; no rock.
G. Whitfield, near Millbrook	650	60	Sand below till.
Mr. Darnell, 2 miles south of Millbrook.	700	190	Mainly blue till, 160 feet; old soil with wood, 2 to 4 feet; blue sand to bottom.
Newark village well	640	110	No rock; mainly till.
C. Sleezer, east of Newark	700	141	Mainly till; rock at bottom.
F. Sleezer, east of Newark	700	140	Entirely till.
S. Sleezer, east of Newark	725	160	No water or rock struck.
I. Anderson, east of Newark	725	160	Soft till, 100 feet; hard till with wood near bottom, 60 feet; St. Peter sandstone at bottom.
Sec. 4, T. 35, R. 6 E	725	150	Entirely in till.
Sec. 4, T. 35, R. 6 E	725	161	Limestone at bottom.
Holderman's Grove	700	50	Mainly till; no rock.
Big Grove	725	150	Two wells enter limestone below till at this depth.

GRUNDY COUNTY.

GENERAL STATEMENT.

Grundy County is situated east of Lasalle County and includes the head of the Illinois River. It has an area of 440 square miles, and Morris

is the county seat. The Illinois River leads westward through the north-central portion of the county. The tributaries of the Illinois, however, have an eastward course, those on the north bearing southeast, and those on the south northeast. This peculiar feature, as previously indicated, is occasioned by the slopes of the plain, or basin, encircled on the north, west, and south by the Marseilles moraine, from which there is a gradual descent to the center of the basin near the head of the Illinois River. The river has cut this moraine at the town of Marseilles and thus opened an outlet from the basin.

The surface of this county is almost entirely a smooth plain. The Minooka Ridge touches a few square miles in the northeast corner of the county and the inner slope of the Marseilles moraine touches the extreme northwest and southwest corners. In the eastern part there are a few dunes which diversify the otherwise monotonous plain.

In the lowest part of the basin and along the Illinois River the drift is thin and wells ordinarily enter the rock. On the Minooka Ridge the drift probably averages at least 100 feet and wells have occasionally been sunk beyond that depth without entering rock. On rising toward the Marseilles moraine in the western portion of the county there is a corresponding increase in thickness of drift, and rock is not found at less than 100 feet near the western line of the county, except in the trench cut by the Illinois River.

The eastern portion of the county is covered with sand, which was probably deposited by a lake occupying that portion of the basin. The depth is usually but a few feet and the underlying drift is mainly blue till. The slopes of the Marseilles moraine in the western part of the county, and the Minooka Ridge in the northeastern part, rise above the level of this sand and are composed mainly of blue till to the depth ordinarily reached by wells, 25 to 50 feet or more.

The low portion of the county affords a favorable condition for obtaining flowing wells from the St. Peter sandstone and lower strata, and several such wells have been sunk. A few flowing wells have been obtained from the drift on the slopes of the Marseilles moraine and there is usually sufficient hydrostatic pressure to bring the water nearly to the surface throughout the county. It is, therefore, highly favored in conditions for obtaining water.

INDIVIDUAL WELLS.

At Morris the public water supply is obtained from artesian wells about 600 feet in depth which terminate in the St. Peter sandstone. The head is sufficient to raise the water a few feet above the surface. Shallow wells are obtained in the vicinity of this city, at depths of 14 to 30 feet, either in gravel or in sandy shale of the Coal Measures.

At Minooka a boring was sunk to a depth of 2,100 feet, which terminated in the Potsdam sandstone. A very strong water vein was struck at about 1,985 feet, with sufficient head to rise 46 feet above the surface, or 660 feet above tide. Although situated on the crest of the ridge, wells are obtained in this village at depths of 30 or 40 feet.

At Carbon Hill the public water supply is from an artesian well 1,900 feet in depth, from which water flows direct through the mains.[1]

At Coal City wells are usually obtained at about 12 feet in the sand which covers that portion of the county. The waterworks are used for fire protection only.[1]

At Braceville wells are found at the bottom of the sand and also beneath the till at depths of 30 or 40 feet. Rock is entered at Braceville at about 45 feet.

At Gardner wells are usually obtained from gravel or sand below till at 40 or 50 feet. Coal shafts enter rock at about 60 feet. Mr. Thomas Cumming, of Gardner, one of the State mine inspectors, reports that water veins of excellent quality are found at several horizons in the Coal Measures in the vicinity of the villages just mentioned.[2]

At Mazon wells are ordinarily obtained at depths of 30 or 40 feet, but several deep wells have been made on farms in that vicinity which do not reach rock at a depth of 100 feet. The drift is mainly a blue till.

At Verona, and over an area of several square miles in the vicinity of that village, sandstone is usually entered at about 75 feet.

[1] Manual of American Waterworks, 1897. [2] Communicated to the writer.

The following well records include the deepest obtained in the county:

Table of wells in Grundy County.

Owner and location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
S. Frey, W. part T. 34, R. 6 E	680	190	Drift, mainly till, 140 feet; sandstone, 12 feet; shale, 38 feet. St. Peter sandstone at bottom.
I. Hoge, jr., sec. 15, T. 34, R. 6 E	600	58	Flowing well from drift.
S. Hoge, sec. 22, T. 34, R. 6 E	600	54	Flowing well from drift.
O. Dix, sec. 8, T. 34, R. 6 E	650	300	Drift, 96 feet; limestone, 100 feet; sandstone, 105 feet.
Mr. Morwick, near preceding	650	300	Drift, 100 feet. Section as in preceding.
Secs. 23, 24, 25, and 26, T. 34, R. 6 E.	575	60	Shale below drift near bottom.
Secs. 21 and 26, T. 34, R. 6 E	600	125	Rock near bottom.
Secs. 15, 16, 21, and 22, T. 34, R. 7 E.	575	50	Shale below till at about 50 feet.
Secs. 23 and 27, T. 34, R. 7 E	550	24	Wells in sand below till.
Secs. 28 and 33, T. 34, R. 7 E	540	30	Shale below till at about 30 feet.
I. Hoge, sec. 31, T. 34, R. 7 E	550	42	No rock; mainly till.
Secs. 12 and 13, T. 34, R. 7 E	550	50	Mainly through sand and gravel. Rock at bottom.
Secs. 21 and 22, T. 34, R. 7 E	575	45	Drift about 45 feet.
Secs. 7 and 18, T. 34, R. 8 E	550	50	Mainly sand; drift about 50 feet.
Sec. 12, T. 33, R. 7 E	510	60	Rock at bottom. Wells in vicinity enter rock at shallower depth.
Sec. 23, T. 33, R. 6 E	575	81	Till, 30 feet; sand, 51 feet.
Sec. 24, T. 33, R. 6 E	575	113	Till, 50 feet; sand, 63 feet.
Sec. 13, T. 33, R. 6 E	500	50	Entirely sand.
Sec. 22, T. 33, R. 6 E	590	120	Till, 18 feet; sand, 102 feet.
Sec. 21, T. 33, R. 6 E	590	120	Till, 40 feet; sand 80 feet.
Sec. 34, T. 33, R. 6 E	600	55	Till, 20 feet; sand 35 feet.
Sec. 35, T. 33, R. 6 E	600	50	Gravel below till at bottom.

WILL COUNTY.

GENERAL STATEMENT.

Will County is situated on the eastern border of the State, immediately south of Dupage and Cook counties, and has an area of 850 square miles, with Joliet as the county seat. Its northwestern portion is crossed by the broad valley of the Des Plaines, formerly the outlet of Lake Chicago. The extreme western part is traversed in a southward course by the Dupage River. The southwest corner is crossed in a northwestward direction by

the Kankakee, which joins the Des Plaines, just west of the county line, to form the Illinois River.

The northwest part of the county and adjacent portions of Dupage and Cook counties are occupied by the Valparaiso morainic system from which drainage lines lead to the southwest across a much lower region, the altitude of the crest being about 750 to 800 feet, while the plain southwest of it stands but 600 feet in average elevation, and scarcely reaches 675 feet where highest. The extreme western border of the county is occupied by the Minooka till ridge from the north line southward to the head of the Illinois River.

Rock is extensively exposed in the southwestern and western parts of the county, but is seldom encountered even in wells in the eastern part. The average distance to rock in 55 wells situated in the low district outside the Valparaiso moraine is 43 feet, which probably represents the approximate average for that portion of the county. Forty-two other wells, situated mainly along the Valparaiso moraine, though having an average depth of 76 feet, do not enter rock. The thickness in that portion of the county probably exceeds 100 feet, though in places rock is near the surface. Along the valleys there are extensive gravel or sand deposits and the southwestern portion of the county is covered with sand dunes. The Valparaiso moraine and the plain southwest of it have at surface till to a depth of 25 to 50 feet or more, beneath which sand and gravel is often found. The presence of this sand and gravel beneath the till renders this county one especially well favored for an adequate supply of excellent water at shallow depths. Very few wells, aside from deep artesian wells, have been sunk to a depth of 100 feet.

INDIVIDUAL WELLS.

The city of Joliet obtains its public water supply from three wells 1,200 feet and one 1,700 feet in depth. The shallower ones terminate in the St. Peter sandstone and the deeper one probably in the Lower Magnesian, though it may reach Potsdam strata. The head is about 40 feet above the surface, or 575 feet above tide. Each well has a capacity of about 500 gallons per minute. The water is moderately hard, but of pleasant taste. The deepest well is cased only 325 feet and its water has a temperature of 45° F. Mr. F. W. Dewey, superintendent of waterworks, reports that the water can be lowered by pumping to a depth of 70 feet below the

surface, and that wells to a distance of nearly one-half mile are perceptibly lowered by heavy draughts on any one well. Many other artesian wells are made within the limits of the city and the rock strata are drained to about their fullest capacity. A well at the Joliet Steel Mill reaches a depth of 2,076 feet, and one at the State Penitentiary a depth of 1,948 feet, both terminating in Potsdam sandstone. Another well at the penitentiary is but 553 feet in depth and obtains its supply probably from the Galena limestone.

Artesian wells are obtained at Lockport, but no data have been collected. There are also artesian wells at Wilmington and Braidwood, and an artesian well has been sunk on the farm of Judge Caton, about 8 miles west of Joliet. The Braidwood well was made with a diamond drill, and the carefully preserved core formed an interesting exhibit at the World's Fair in Chicago, in 1893. The depth is 900 feet, but the main supply of water is from a porous sandstone at 655 to 855 feet, the lower 45 feet being in a limestone with green shale interbedded. The well formerly overflowed, but at present stands near the level of the well mouth (588 feet above tide). The water is slightly sulphurous, but not of unpleasant taste.

At Wilmington the best supply of artesian water is obtained at a depth of about 600 to 635 feet, though in some cases strong water veins are struck at 100 feet and several wells obtain water at 250 to 450 feet. The head at these wells is about the same as at Braidwood, slightly below 600 feet above tide.

The following table of wells on the Valparaiso morainic system includes the deepest of which records were obtained. The sections begin near the State line and proceed westward and northward across the county.

Wells on the Valparaiso morainic system in Will County.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Between Goodnow and State line.	750	100	Several wells 50 to 100 feet; mainly till; no rock encountered.
Endor and vicinity	685	75	Drift, mainly till, 75 feet; rock near bottom.
3 miles east of Crete	725	40	Rock entered at 40 feet.
Crest of moraine south of Crete.	750	130	No rock struck.
Crete	720	80	Rock at 80 feet. Many wells from sand at 25 to 40 feet.

Wells on the Valparaiso morainic system in Will County—Continued.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Sec. 8, T. 34, R. 14 E	725	52	Till, 23 feet; sand, 29 feet.
Mr. Piepenbrinck, sec. 11	725	106	Gravel below till at bottom.
Sec. 1, T. 34, R. 14 E	725	77	No rock struck.
C. L. Pease, sec. 28	775	112	No rock, mainly blue till.
Beecher (east part)	720	106	No rock, mainly blue till.
2 miles east of Beecher	725	50	Old soil beneath glacial gravel at 50 feet.
Monee and vicinity	800	50	Wells in sand below till at 40 to 50 feet.
One-half mile north of Monee.	800	180	Mainly blue till.
Sec. 4, T. 34, R. 13 E	775	70	Till, 50 feet; sand, 20 feet.
Sec. 10, T. 34, R. 13 E	800	92	No rock, mainly blue till. Several wells.
Sec. 12, T. 34, R. 13 E	750	65	Three wells, similar: Till, 55 feet; sand, 10 feet; no rock.
Peotone and vicinity	725	60	Wells, 40 to 60 feet, mainly till; no rock.
North part T. 33, R. 12 E	675	60	Similar to preceding.
Sec. 26, T. 34, R. 12 E	725	55	No rock, mainly till.
Sec. 36, T. 34, R. 12 E	725	50	No rock, mainly till.
Morainic crest, T. 34, R. 12 E	750	100	Drift exceeds 100 feet in several wells.
Morainic crest, T. 35, R. 12 E	750	100	Wells through till; no rock.
A. Reid, sec. 13, T. 35, R. 12 E	710	10	Rock entered at 10 feet.
Frankfort	758	90	Wells 70 to 90 feet, mainly till; no rock.
Mr. Baumgartner, 1 mile southwest of Frankfort.	760	135	No rock struck.
Spencer, at Elevator	711	75	Mainly till; sand at bottom.
Sec. 8, T. 35, R. 11 E	630	48	Yellow till, 15 feet; sand, 15 feet; yellow till, 18 feet.
Sec. 18, T. 35, R. 11 E	650	60	Cemented gravel below blue till near bottom.
New Lenox and vicinity	630	33	Wells in valley enter rock at 7 to 33 feet.
Sec. 35, T. 35, R. 11 E	720	82	Yellow clay, 8 feet; gravel, 14 feet; blue till, 60 feet.
Sec. 9, T. 36, R. 11 E	750	108	Drift, mainly till, 95 feet; limestone, 13 feet.
Sec. 12, T. 36, R. 11 E	710	104	No rock; mainly till.
Sec. 12, T. 36, R. 11 E	720	114	No rock; mainly till.
Sec. 13, T. 36, R. 11 E	700	115	No rock; mainly till.
Sec. 32, T. 36, R. 11 E	675	80	Till, 68 feet; gravel, 12 feet.
Des Plaines bluff, east of Romeo	640	62	Till, 50 feet; sand, 12 feet.
Secs. 9, 10, 11, and 12, T. 37, R. 10 E.	725	60	In cemented gravel below till.
Sec. 11, T. 37, R. 10 E	700	96	No rock struck.
Mr. Godfrey, sec. 13	760	160	Till, 100 feet; gravel, 10 feet; sand, 40 feet; limestone, 10 feet.
Mr. Gowdy, near Dupage post-office.	650	50	Rock in one well at 35 feet; none in another at 50 feet.

The following table serves to illustrate the depth and character of drift in the deep wells in the portion of the county outside the Valparaiso system:

Wells in Will County outside the Valparaiso morainic system.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
West border T. 37, R. 9 E	725	130	Wells on Minooka Ridge penetrate till 80 feet, beneath which is sand extending to rock at about 130 feet.
East half of T. 37, R. 9 E	650	20	Wells usually enter rock at about 20 feet; drift gravelly.
T. 35, R. 9 E	620	30	Gravelly drift between Dupage and Des Plaines River; wells at about 30 feet.
County Infirmary, T. 35, R. 9 E.	620	40	Mainly through gravel.
Sec. 36, T. 35, R. 9 E	575	45	Till with thin sand beds.
Sec. 7, T. 34, R. 10 E	600	80	Flowing well, mainly till. Thought not to enter rock.
Sec. 25, T. 34, R. 9 E	630	60	Yellow till, 20 feet; blue till, 40 feet; limestone, 6 feet.
Joliet Mound, sec. 19, T. 35, R. 10 E.	560	60	Cobble and gravel, 45 feet; clay, 15 feet; limestone at bottom.
NE. corner T. 35, R. 10 E	675	110	Wells 90 to 110 feet; mainly till; no rock.
Elwood tile factory	640	70	Till, with thin beds of gravel. Neighboring wells enter rock at 50 feet.
Sec. 13, T. 34, R. 10 E	650	32	Till to rock, at 32 feet.
Sec. 14, T. 34, R. 10 E	630	28	Drift, mainly till; rock at 28 feet.
Sec. 20, T. 34, R. 10 E	630	75	Mainly till; rock at 75 feet.
Sec. 24, T. 34, R. 10 E	630	38	Till, 20 feet; sand, 9 feet; till to rock (9 feet).
Sec. 26, T. 34, R. 10 E	650	32	Till, 17 feet; sand, 5 feet; till to rock (10 feet).
Sec. 32, T. 34, R. 10 E	650	58	Rock at bottom.
Sec. 34, T. 34, R. 10 E	660	35	Mainly till; rock at bottom.
Sec. 21, T. 33, R. 10 E	600	90	Drift, mainly till, 49 feet; limestone, 41 feet.
Sec. 6, T. 33, R. 10 E	640	50	Mainly till; rock at bottom.
Sec. 16, T. 33, R. 10 E	660	52	Yellow till, 12 feet; blue till, 40 feet; no rock.
Sec. 34, T. 33, R. 9 E	560	31	Till, 13 feet; sand, 18 feet.
Wilmington and vicinity	560	40	Wells 20 to 40 feet, from gravel.
Braidwood	590	40	Wells 18 to 40 feet; sand, 15 or 20 feet; blue clay, 20 or 25 feet.
2 miles east of Braidwood	590	220	Sand, 20 feet; blue clay, 20 feet; remainder rock, 180 feet.

KANKAKEE COUNTY.

GENERAL STATEMENT.

This county is situated on the eastern border of the State immediately south of Will County, and has an area of 680 square miles, with Kankakee as the county seat. The Kankakee River leads westward through its central portion. The greater portion of the county is imperfectly drained, there being extensive marshes and sandy areas in the southeastern part, and a very level surface in the western, while the northern portion is characterized by occasional sloughs and marshes.

The drift is a comparatively thin deposit along the Kankakee River and its borders throughout the county, but the western, southern, and northeastern portions of the county have a sheet of drift probably not less than 100 feet in average thickness. In the vicinity of the Kankakee the drift consists mainly of gravel or sand, but in its thicker portions on the borders of the county there is generally present a heavy sheet of till.

The wells are of moderate depth throughout the county, there being very few which reach 100 feet, even in the portions where it is necessary to drill into rock.

INDIVIDUAL WELLS.

The public water supply for the city of Kankakee is pumped from the Kankakee River, but there are numerous drilled wells in the city 30 to 90 feet in depth. A small till ridge leading eastward from the vicinity of the court-house affords water at depths of 20 to 60 feet without entering rock. Throughout much of the city, however, rock is found at a depth of 10 feet or less.

A well sunk on the south side of the Kankakee opposite the city reached a depth of 1,000 feet, entering St. Peter sandstone at 900 feet. The water rises within 15 feet of the surface, or to about 605 feet above tide.

At Momence the wells are obtained in limestone at a depth of 12 to 80 feet. A strong well can usually be obtained at a depth of 30 feet. The wells are generally about 5 inches in diameter and are reported to be practically inexhaustible.

In the southeast township of the county several flowing wells have been obtained from sand below a gray clay at depths ranging from 30 to

90 feet. In some cases water fails to reach the surface, though all the wells in that locality have strong hydrostatic pressure.

At St. Anne a few of the wells reach a depth of 80 feet, entering rock at about 60 feet.

At Sherburnville, on the east border of the county, wells frequently reach a depth of 50 feet without entering rock. They penetrate 25 or 30 feet of till, beneath which is sand. Much of T. 32, R. 14 E., which is situated west from Sherburnville, has wells of similar depth and structure, but in the northeast part of T. 32, R. 13 E., rock is often struck at a depth of 30 or 40 feet.

In the vicinity of St. George, in the northern part of the county, wells usually enter rock at a depth of 10 or 20 feet. This thin drift characterizes much of northern Kankakee County westward beyond Manteno.

In a few places in the west part of T. 32, R. 14 E., and in T. 32, R. 13 E., well drillers report having passed through an old soil below the blue till near the base of the drift.

At Deselm post-office, in the northwest part of the county, there is a drift ridge in which the distance to rock is about 60 feet, the level being about the same beneath the ridge as on the bordering plain. In the southwest part of the county on the border of the Marseilles moraine records of 6 wells were obtained which reach rock at a depth of 100 to 162 feet. The altitude is about 700 feet above tide, or nearly 100 feet above the Kankakee River at the city of Kankakee. The rock surface is therefore not much lower than at Kankakee. In the vicinity of Irwin and Dickey and Hersher rock is usually entered at 40 to 60 feet, but at Buckingham the drift is about 90 feet in depth. Two flowing wells have been obtained at Dickey from beds of gravel and sand at the base of the drift. The underlying rock is shale.

From Union Hill eastward to Kankakee the drift is generally of slight depth, but from this village westward to the county line its thickness is 50 to 100 feet or more.

IROQUOIS COUNTY.

GENERAL STATEMENT.

Iroquois County is situated south of Kankakee on the east border of the State, and has an area of 1,120 square miles, being exceeded in size

only by McLean and Lasalle counties. Watseka, the county seat, is situated a few miles east of the geographic center. The Iroquois River enters the county from Indiana in the northeast part, and after passing westward to Watseka it turns northward and enters the Kankakee a short distance north of the county line. This stream, with its tributaries, drains almost the entire county. It is a widely-branching drainage system, yet the number of drainage lines is too few to afford escape for the surplus rainfall, and there are extensive marshes within its drainage basin.

The county is mostly occupied by a basin whose borders lie not far beyond the county limits. On the west and south this basin is limited by the prominent Bloomington morainic system; on the north the basin is limited by the Marseilles moraine, which follows nearly the line of Iroquois and Kankakee counties; on the east it finds a natural limit in the Iroquois moraine, which traverses the eastern portion of the county. This basin is due entirely to drift aggregation, for the underlying rock apparently stands higher in the low part of the basin in the northern portion of the county than in the rim of the basin on the west and south.

This basin is found to be a favorable locality for obtaining flowing wells from the drift, and several hundred have already been made, which have been discussed by the writer in the Seventeenth Annual Report of this Survey. There is a perceptible increase of head in passing from north to south. There is an increase also in passing from near Watseka either eastward or westward. There is little doubt, therefore, that the absorbing areas are found on the east, south, and west borders of the basin. This is contrary to the interpretation made by the residents, who quite generally suppose the supply to be derived from the Kankakee marsh on the northeast, a marsh whose altitude is in the main below the level of the lower parts of this basin.

The drift is largely a soft till to a depth of 75 or 100 feet, though in the northeastern part of the county there is a surface sand a few feet in depth capping the till and which connects with the sand of Kankakee County mentioned above. The till is found to be underlain at many points by a black soil and by beds of peat and shell marl. With the peat and marl there is usually considerable sand, which is a source for the flowing wells. After these beds of peat and sand are penetrated a harder till is entered than the surface sheet. In some cases this till is found to include

beds of peaty soil and sand which afford water for the flowing wells. In one case, near the south border of the county, a buried peat was found to have a depth of 30 feet, showing that a long interval must have elapsed between the deposition of the sheets of drift which it separates. The time need be no longer than has elapsed since the upper till sheet was deposited, for in that same locality there is an instance of the penetration of peat to a depth of 32 feet; there being a kettle-hole with an area of 5 acres which has peat of this thickness, as shown by a series of test borings made by Dr. Ludden, of East Lynn. The thick deposit of buried peat just referred to occurs in the midst of the hard tills and not at the junction of the soft till with the hard till, there being 26 feet of hard brown till above the peat, which in turn is overlain by 80 feet of soft till of the Wisconsin stage.

INDIVIDUAL WELLS.

At St. Mary's, in the northeast part of the county, wells are usually obtained at about 40 feet. One well in the village, however, was sunk to a depth of 140 feet without entering rock; it passed through an old soil at 80 feet, and water from the lower portion of the well rose within 18 feet of the surface. Three wells about a mile west of St. Mary's, at an altitude perhaps 20 feet lower, enter rock at 90 to 100 feet. The drift is mainly till, and water rises within 20 feet of the surface, or to about 630 feet above tide. East from St. Mary's several wells enter rock at about 100 feet, though occasionally a greater amount of drift is penetrated. For instance, in sec. 11, T. 28, R. 11 W., a well 176 feet in depth enters rock at 135 feet. The drift is mainly blue till. Water rises from the rock to within 15 feet of the surface.

At the village of Papineau wells enter rock at 40 to 45 feet and water rises within 5 feet of the surface. In the valley of Beaver Creek, north of this village, at an elevation about 15 feet lower, several flowing wells have been obtained, some being from the drift, others from the rock.

In the vicinity of Martinton rock is entered at about 60 feet. A well 1 mile north of this village, 276 feet in depth, penetrates drift, mainly till, 60 or 65 feet; shale, 15 feet; mainly limestone, 196 feet. The water level is 10 feet below the surface, or 620 feet above tide.

At Pittwood several wells have been sunk to a depth of 100 to 130

feet without reaching rock. Wood is found occasionally near the bottom. Water rises within 15 feet of surface or to about 630 feet above tide. Three miles northwest of this village, in sec. 26, T. 28, R. 13 W., a well penetrates till sheets of different hardness. The upper 45 feet is a soft till, the remainder a hard till. The bed of sand at bottom furnishes water which rises within 3 feet of the surface. In the adjoining section on the south (sec. 35) a well 156 feet in depth does not reach rock. Water rises just to the surface. In sec. 29 of this township a well penetrated an old soil near the base of the drift at a depth of about 95 feet. Wells in that vicinity enter shale at about 100 feet and limestone at about 160 feet.

In the north part of the county, near Chebanse, rock is entered at 80 to 100 feet. About 3 miles east of the village on the farm of O. Sykes, and also on neighboring farms, wells were noted in which beds of peat 20 feet in thickness were found near the base of the drift at depths of 60 to 80 feet.

In the vicinity of Ashkum wells usually enter rock at about 80 feet, though one half a mile west of the village reached a depth of 146 feet before striking rock. There is usually a soft till about 50 feet, beneath which is a harder till, associated in places with sand beds. The water level from wells obtained in the lower part of the drift and upper part of the rock is 10 to 20 feet below the surface, or about 640 feet above tide. Along the border of Langum Creek Valley, in the vicinity of Ashkum, wells enter limestone at 60 to 90 feet. In some cases they obtain water in sand below till at 40 to 60 feet. The water usually rises within 5 or 10 feet of the surface. A well at Mr. Mayo's, about 5 miles northwest of Ashkum, penetrated 120 feet of drift containing a log near the bottom, and terminated in shale at 167 feet. Water stands within 4 feet of the surface, the altitude being slightly lower than at Ashkum. About 3 miles west from this well the records of three wells were obtained which obtain water in limestone at 60 to 68 feet. The head is sufficient to bring the water barely to the surface.

In the vicinity of Prairie Creek, southeast from Ashkum, a few flowing wells have been obtained from the drift at depths of 75 feet or less.

At Danforth wells from the drift 100 feet in depth have a head about 7 feet below the surface or about 640 feet above tide. The last edition of the Manual of American Waterworks reports a deep well in progress, but

no good supply had been obtained though sunk to a depth of 1,200 feet. Near this village, at Mr. Eden's, a well 168 feet in depth penetrates—

Section of Eden well near Danforth, Illinois.

	Feet.
Soft till	70
Hard till	60
Shale	38

It obtains water in limestone at bottom. A neighboring well obtains water at 72 feet, in sand below a soft till. Wood was found just above the water vein.

At La Hogue several flowing wells have been obtained from the drift at depths of 70 or 80 feet. They are mainly through soft blue till. Flowing wells are found at a similar depth at Ridgeville and in the interval between these two villages. Occasionally a well only 40 or 45 feet in depth has sufficient head to nearly reach the surface.

At Gilman flowing wells are obtained from the drift at depths of 75 to 150 feet. It is designed to use such wells for a public water supply. Occasionally wells are sunk to the underlying rock, which is reached at 190 or 200 feet. The shallow wells in Gilman are obtained at 12 to 16 feet.

At Onarga several wells have been sunk to a depth of 90 to 160 feet from which water rises within 10 or 15 feet of the surface, or to about 660 feet above tide. The public supply is from three wells of this class.[1] In a portion of this village there is surface sand to a depth of 12 to 18 feet, at the bottom of which wells are often obtained. The following three borings are reported in the geology of Illinois. A coal boring near Onarga is thought to have reached a depth of 400 feet without encountering rock, though it terminated at an elevation but 260 feet above tide, or about the level of the Mississippi River at Cairo. The reliability of this record appears questionable, it being given from memory some years after the boring was made. A boring between Onarga and Gilman is reported to have reached rock, thought to be Lockport (Niagara) limestone. at 268 feet, the drift section being as follows:

Seetion of a boring between Onarga and Gilman, Illinois.

	Feet.
Blue and red clay	98
Sand and soft sediment	140
Hardpan	10
Hard stony clay	20
Total	268

[1] Manual of American Waterworks, 1897.

At Onarga a coal boring reached the first rock at about 300 feet. The rock was interpreted to be Hudson River (Cincinnati) shale.[1]

In the vicinity of Crescent many flowing wells have been obtained at depths of 80 to 120 feet. There is scarcely a section in the south half of T. 27, R. 13 W., or any part of T. 26, R. 13 W., in which the water does not overflow or rise within 10 feet of the surface. The public water supply at Crescent is from four wells of this class.[2] Many wells south of Crescent pass through an old soil at depths varying in the different wells from 60 to 80 feet below the surface. Above the soil the till is not nearly so hard as that below.

At Watseka many flowing wells have been obtained from the drift at depths of 100 to 150 feet, and the first rock is encountered at about 165 feet. The public water supply is from a well 150 feet in depth, which has sufficient capacity to supply the city. In the higher portions of the city the water falls short a few feet of reaching the surface. The mayor reports that no shallow wells are in use and that few wells are obtained at less depth than 85 feet. The surface is coated to a depth of a few feet with sand, beneath which there is a soft blue till extending to a depth of 85 or 100 feet. Beneath this a hard till with alternating sand beds is penetrated.

Along the Iroquois Valley above Watseka in this county, and also in Newton County, Indiana, flowing wells are obtained from the drift at depths of 70 to 120 feet. A well at the village of Iroquois, 88 feet in depth, is reported to have passed through a black soil below blue till near the bottom.

North of the Iroquois Valley, on the Iroquois moraine, in the vicinity of Donovan, several deep borings have been made which enter rock at depths of 125 to 170 feet and obtain their supply from limestone at 200 feet or less. The water in that locality rises within about 40 feet of the surface, or 635 feet above tide, which is nearly the altitude in neighboring lower districts to the north and west. These deep wells in several instances encounter an old soil at about 140 feet. Hard till sets in at about 100 feet. No instance of the occurrence of a soil at the top of the hard till was reported, though it is often present in the neighboring districts, as already noted.

South of the Iroquois River, in the vicinity of Sheldon, the drift has a thickness of 100 to 120 feet and is mainly a blue till. On the moraine

[1] Geol. of Illinois, Vol. IV, pp. 237–238. [2] Manual of American Waterworks, 1897.

south of this village, in sec. 11, T. 26, R. 12 W., a well 156 feet in depth entered rock near the bottom and struck a bed of coal. Two other borings located in the north part of T. 25, R. 11 W., enter rock and strike coal at only 60 feet. Several other wells in that locality reach a depth of 160 feet without entering rock. They penetrate about 80 feet of soft till, beneath which is a hard till, in which little sand is found at less than 160 feet from the surface.

Along Sugar Creek Valley, north of Milford, three wells were noted which strike an inflammable gas in sand below till at a depth of 40 feet. In the vicinity of Milford wells are usually obtained at depths of 40 to 60 feet, and water does not rise usually within less than 25 feet of the surface, or to about 645 feet above tide. The public supply is from two 8-inch wells 60 feet deep.[1] A boring at Milford in search of coal has the following section:

Section of a coal boring at Milford, Illinois.

	Feet.
Soft till	45 to 50
Hard till, with some sand beds	70
Shale	88
Limestone at bottom	0
Total	208

West from Milford, for 6 or 8 miles, several wells have been sunk to depths of 100 to 110 feet, which obtain water in sand below the blue till. Its head is 20 feet or more below the surface.

In the southeast part of Iroquois County a black soil has been found in a few wells at about 160 feet. These wells penetrate 90 or 100 feet of soft till and 50 feet or more of hard till before entering the soil.

At Wellington, wells are often obtained at a depth of 70 feet, which have a head about 20 feet below the surface, or 680 feet above tide. They are said to enter a hard till in the lower 10 or 15 feet.

At Clayton flowing wells are obtained at a depth of 60 or 70 feet and also at about 100 feet. The deeper ones penetrate an old soil near the bottom. The head at these wells is about 675 feet above tide. Four miles south of Clayton, in sec. 27, T. 24, R. 13 W., two flowing wells have been obtained, one at 50 feet, the other at 80 feet, whose head is nearly 700 feet above tide. A mile farther south is the well noted above, which penetrated

[1] Manual of American Waterworks, 1897.

a buried peat 30 feet in thickness. It is on the farm of Dr. Ludden, in sec. 33, T. 24, R. 13 W. The following is the section furnished by Dr. Ludden:

Section of Ludden well, 5 miles south of Clayton, Illinois.

	Feet.
Mainly blue till	80
Hard brown till	25
Peat	30
Coarse sand	9
Total	144

At Cissna Park the public water supply is from a flowing well, the water being pumped from the receiving reservoir to the standpipe.[1]

North from Clayton, in the vicinity of Ash Grove, many flowing wells are obtained at a depth of about 100 feet. They penetrate alternations of sand and soft blue till to a depth of 55 or 60 feet, below which a hard gray till is entered with which thin beds of gravel, yielding water, are associated. Several wells are reported to pass through a soil containing wood at a depth of about 100 feet, or some distance below the top of the hard till. In the Ash Grove timber belt wells are occasionally sunk to a depth of 150 feet and penetrate a section similar to the preceding, passing through soil and wood at 95 or 100 feet, beneath which are alternations of hard till and sand. Occasionally a well passes through a heavy deposit of gravel or sand beneath the soft till, but usually the sand and gravel beds are thin.

In a low tract known as Shavetail Slough, in the northeast part of T. 25, R. 13 W., several wells have been sunk to a depth of about 160 feet, which penetrate a black soil below hard till at 150 to 158 feet, and obtain water in sand at bottom. The head is sufficient to barely reach the surface.

In the vicinity of Buckley, and thence southeast to Cissna Park, flowing wells are frequently obtained at depths of but 50 feet, in sand or gravel below a soft blue till. At Buckley the water rises within 8 to 15 feet of the top, but on low ground west of the village a few wells overflow at an altitude about 690 feet above tide. The public supply is from a flowing well.[1]

In the vicinity of Thawville flowing wells are obtained only on the lowest ground at an altitude about 685 feet above tide. They frequently reach a depth of 135 or 140 feet, and pass through a black soil containing wood near the bottom.

[1] Manual of American Waterworks, 1897.

In the vicinity of Loda wells are often sunk to a depth of 100 feet, mainly through till. The water rises as in the flowing well district, but the altitude is much too high for an overflow, being about 775 feet above tide.

FORD COUNTY.

GENERAL STATEMENT.

Ford County is situated west of Iroquois and also extends a short distance along the western portion of the south border of that county. It is a narrow tract, its northern two-thirds being but 6 miles in width. It has an area of 490 square miles and Paxton is the county seat. It occupies a comparatively elevated tract from which streams discharge in all directions. From the northern portion the drainage is in part tributary to Mazon Creek, which enters the Illinois at Morris; in part to the Illinois-Vermilion River, which enters the Illinois at Lasalle, and in part to the Iroquois River. The southern portion divides its waters between the Iroquois, the Wabash-Vermilion, and the Sangamon rivers.

The southern half of the county is occupied by the Bloomington morainic system, whose highest points have an altitude about 860 feet above tide. The extreme northern end is occupied by the Marseilles system. Between these morainic systems there is a plane tract which constitutes the westward extension of the basin of Iroquois County, and like it is favorably situated for obtaining flowing wells. Its altitude is 650 to 700 feet.

The entire county is covered with a nearly continuous sheet of blue till 100 feet or more in average depth, beneath which there is apparently a series of hard till deposits interbedded with sand and gravel, similar to those in Iroquois County already discussed.

Records of eight wells which reach the rock show an average thickness of 211 feet of drift, which is perhaps a fair approximation to the average for the county. Many deep tubular wells have been sunk in this county, some of them reaching depths of over 200 feet without entering rock. The greatest thickness reported within the county is at the artesian well in Paxton, where 440 feet of drift was penetrated.

INDIVIDUAL WELLS.

The public water supply at Paxton is from wells about 150 feet in depth, obtained in sand and gravel below a sheet of till. The water rises

about 100 feet and is practically inexhaustible. The artesian well at this city, referred to above, has a depth of 2,670 feet, but no further data concerning it have been obtained.

At Gibson the public water supply is obtained from three wells 55 feet in depth and 7 inches in diameter. Many private wells are obtained at 12 to 25 feet, though a few are 45 to 55 feet. They are largely through sand and gravel, the town being situated on a plain just outside the Bloomington morainic system, which apparently received a coating of sand and gravel as a morainic outwash. A boring for coal at this city was sunk to a depth of 705 feet and penetrated 175 feet of drift.

The following table of sections of deep wells is begun at the northern end of the county and proceeds southward. It includes the deepest of which records were obtained:

Deep wells in Ford County.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Cabery, village well	706	240	Depth given by Man. Amer. Waterworks, 1897.
Cabery, coal boring	706	200	Thin beds of shale and coal overlying limestone, entered at about 200 feet, at base of drift.
Kempton, village well	737	....	Reported in Manual of American Waterworks that public water supply is from a well.
Kempton, several wells	737	176	Drift mainly till; rock at about 175 feet.
Sec. 33, T. 29, R. 9 E	750	185	Rock struck at bottom; drift mainly till.
Sec. 24, T. 29, R. 9 E	700	196	Enters rock at bottom.
Sec. 11, T. 28, R. 9 E	680	203	Drift, 150 feet; shale with two coal beds, 53 feet.
Vermilion Swamp	650	75	Flowing wells from sand below till.
Sec. 5, T. 27, R. 9 E	650	75	Flowing wells from sand below till.
Sec. 9, T. 26, R. 9 E	650	23	Three flowing wells 20 to 23 feet in depth.
Secs. 10, 13, and 14, T. 26, R. 9 E.	650	20	Several flowing wells from drift at about 20 feet.
Piper, several wells	678	65	Flowing wells at about 65 feet; five water veins penetrated; in sand between tills.
Sec. 22, T. 27, R. 9 E	650	95	Flowing well, section as follows: Yellow till, 10 feet; soft blue till, 30 or 40 feet; hard blue till, 25 or 30 feet; black muck, 20 feet; sand and gravel at bottom.
Sec. 17, T. 27, R. 9 E	650	165	Harder till in lower than in upper half; limestone near bottom.
East part Ts. 26 and 27, R. 9 E.	675 700	60 80	Several flowing wells at 60 to 80 feet.
Sec. 31, T. 26, R. 9 E	800	240	Soft till, 130 feet; harder sandy drift, 110 feet; no rock.

Deep wells in Ford County—Continued.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Sec. 7, T. 25, R. 9 E	800	237	Soft till, 1 0 feet; sand, 20 feet; blue clay, 20 feet; cemented sand and gravel at bottom.
Sec. 7, T. 25, R. 9 E	800	196	Yellow till, 8 feet; sand and gravel, 40 feet; blue till with thin sand beds, 95 feet; reddish till, 10 feet; brown till, 26 feet; sand at bottom, 10 feet.
Roberts No. 1	780	200	No rock; log at about 100 feet.
Roberts No. 2	780	117	Blue till, 91 feet; hard gray till, 24 feet; sand at bottom.
Sec. 25, T. 25, R. 8 E	800	240	Mainly blue till, 125 feet; black sand, 6 or 8 feet; blue till, 80 or 85 feet; sand, 20 feet.
1½ miles southeast of Sibley	825	240	No rock or water; mainly blue till.
Melvin	808	140	Wells 115 to 140 feet; hard till near bottom.
Sec. 2, T. 24, R. 9 E	775	200	Till, 120 feet; sand, 80 feet.
Sec. 11, T. 24, R. 9 E	775	201	Yellow till, 16 or 18 feet; blue till, 70 or 75 feet; blue sand, 85 feet; black soil, 2 feet; brown sandy clay, 11 feet; sand, 5 feet.
Sec. 36, T. 24, R. 9 E	800	115	No rock struck.
Northwest part T. 24, R. 9 E	750	117	Wells 110 to 117 feet through till.
Near Henderson Station	775	80	Much sand and gravel in wells 80 feet in depth.
Sec. 28, T. 23, R. 10 E	750	155	Mainly blue till; sand at bottom.
Tile factory in Ten-Mile Grove	750	73	Yellow clay, 10 or 12 feet; gravel, 6 feet; blue clay, 12 or 14 feet; blue clayey sand, 18 feet; sand, 25 feet.
Paxton and vicinity	775	150	Strong wells at 100 to 150 feet in sand below till. Inflammable gas in several wells.
Kirk Station	761	140	Mainly blue till, 98 feet; sand, 42 feet.
Between Paxton and Kirk	775	175	Wells 100 to 175 feet penetrate 80 or 100 feet of till, then sand and gravel to bottom.
Sec. 29, T. 23, R. 14 W	750	116	Alternations of sand and till.

LIVINGSTON COUNTY.

GENERAL STATEMENT.

Livingston County is situated west of Ford and Kankakee counties, its western border reaching nearly the middle of the State. It has an area of 1,026 square miles, and Pontiac is the county seat. Vermilion River traverses the county from southeast to northwest nearly centrally. Its tributaries are almost entirely on the western side of the stream, the eastern side being occupied by the Marseilles morainic system and an earlier

moraine (Chalsworth-Cayuga Ridge) classed in the Bloomington system. The northeast part of the county drains northward through Mazon Creek.

Aside from the moraines just referred to, which traverse the central portion of the county in a northwest to southeast course, and which occupy a belt with an average width of about 10 miles, the surface of the county is very flat. Nearly all the streams of the county flow in mere ditches channeled to a level but a few feet below the plains.

With the exception of a narrow strip along Vermilion River from near Fairbury to Streator, where rock is frequently exposed, the county has a heavy deposit of drift averaging possibly 150 feet in thickness.

There appear to be buried valleys traversing the county whose rock floors are 150 to 200 feet below the general level of the rock surface. In such valleys the drift is over 300 feet in thickness. On the borders of Vermilion River nearly all of the thin sheet of drift is sand and gravel. With this exception the county is generally covered with a thick sheet of blue till, which is oxidized for a few feet at the surface. On the Marseilles moraine in this county a blue till is found at less depth than at any other points noted in the State, in places within 2 or 3 feet of the surface, there being very little yellow or oxidized till. Usually the yellow till is 6 to 10 feet in depth both on this moraine and later ones.

Nearly all the well sections obtained in this county are located in the northeast one-half, the southwest part having been covered only by a hasty reconnaissance. Along the Marseilles moraine and also on the plain to the northeast wells are frequently sunk to a depth of 100 feet or more, and better supplies appear to occur at that depth than nearer the surface.

INDIVIDUAL WELLS.

The public water supply at the city of Dwight is obtained from two wells sunk to a depth of 135 feet in the glacial drift. The water rises within 5 feet of the surface. A boring for coal at this town entered shale at about 100 feet. The record of a private well in the northeast part of the town is as follows:

Section of well at Dwight, Illinois.

	Feet.
Yellow till	17
Blue till	83
Hard yellow till	17
Total	117

Sand at bottom from which water rises within 5 or 6 feet of surface.

At Odell wells are obtained at 30 or 40 feet. The drift varies greatly in thickness within the limits of this village. A well at the Chicago and Alton Railway station entered rock after penetrating 138 feet of till; another, on the Spencer farm near the western limits of the town, entered rock at 168 feet, but a boring made by Mr. Matteson in the south part of the town penetrated 360 feet of drift. An experimental gas boring about 3½ miles southwest of Odell penetrated 300 feet of drift. The deep drift at Mr. Matteson's well in Odell is mainly till to a depth of 200 feet, beneath which is sand.

At Nevada wells are usually obtained at 30 or 40 feet, but records of two borings were collected which failed to obtain water at a depth of 100 feet. They are mainly through blue till.

At Cornell and in its vicinity wells are obtained at about 20 feet in sand and gravel, the village being located on the low gravelly plain bordering Vermilion River.

At Pontiac wells frequently enter limestone at a depth of 10 to 25 feet and obtain water at comparatively shallow depths. The public supply is pumped from Vermilion River.[1] An area of sandy drift extends several miles south of this city and wells are there obtained at shallow depth without entering rock.

At Fairbury the public water supply is from a well 2,002 feet in depth, from which water rises within 60 feet of the surface. The well is cased about 365 feet. Wells are usually obtained in that vicinity at about 25 feet in a gravelly drift. Coal shafts in the vicinity enter rock at 50 to 90 feet.

At Forest strong wells are obtained at 25 or 30 feet and many wells are only 10 or 12 feet in depth. Coal shafts and other borings in the vicinity show the drift to be about 150 feet in thickness and largely till in the lower part.

At Chatsworth the public water supply is from a well sunk to a depth of 67 feet in the glacial drift, mainly through till. Several wells in this village are about 50 feet in depth, and a few are 80 feet, without entering rock. Two coal borings reported in the Geology of Illinois show much difference in the distance to rock. One in the southeast part of sec. 4 enters rock at 84 feet, while another, one mile east, at about the same ele-

[1] Manual of American Waterworks, 1897.

vation, struck rock at 221 feet.[1] The latter boring had hard till in the lower part of the drift, while the former passed through a "dirt bed with wood" just before entering rock.

In the vicinity of Risk and Strawn, in the south part of the county, there is about 90 feet of drift as determined by coal borings, but wells are usually obtained at 50 feet or less in sand below till.

The public supply at Flanagan is reported by the Manual of American Waterworks to be from an artesian well, but no data are given as to depth or head.

Coal borings made at the villages of Cullom, Saunemin, and Campus, in the east part of the county, penetrate 171, 162, and 125 feet of drift, respectively, but wells at these villages are obtained at moderate depths, seldom exceeding 40 feet in sand or gravel below till. The Manual of American Waterworks reports that Campus obtains its public water supply from a driven well.

In some places water is very difficult to obtain at moderate depths; thus, at the village of Griswold, several borings have been sunk to a depth of 75 feet without obtaining strong wells.

Outside the villages just discussed only a few records of wells have been obtained, and these include the deepest of which the writer has obtained information:

Wells in Livingston County.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Sec. 1, T. 30, R. 5 E	700	216	Rock entered at about 200 feet.
Sec. 12, T. 30, R. 5 E	700	135	Water from sand below blue till.
Sec. 18, T. 30, R. 5 E	750	80	Mainly till; no rock.
Mr. Adams, at Blackstone	733	200	Rock entered at 160 feet; drift mainly till.
Mr. Budd, at Budd Station	702	160	Enters rock at 160 feet.
Sec. 14, T. 29, R. 5 E	700	130	Mainly till; no rock.
Northeast part T. 39, R. 5 E	700	100	Several wells 70 to 100 feet, from sand below till.
Sec. 25, T. 29, R. 5 E	650	130	Flowing well from sand below till.
Sec. 27, T. 29, R. 5 E	650	78	Several wells 60 to 78 feet; from sand below till.
Sec. 33, T. 29, R. 6 E	700	60	Flowing well from sand below till.
Cayuga	685	100	Rock at 100 feet; drift mainly till.
4 miles south of Odell	700	68	Flowing well from sand below till.

[1] Geology of Illinois, Vol. VI, pp. 243, 244.

Wells in Livingston County—Continued.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Sec. 33, T. 29, R. 7 E	725	185	No rock struck; mainly till.
Sec. 29, T. 28, R. 8 E	700	90	Mainly blue till.
Sec. 36, T. 28, R. 8 E	675	80	No rock; enters hard till at 56 feet.
Sec. 16, T. 28, R. 7 E	675	130	Several wells in sand below till.
Sec. 2, T. 27, R. 8 E	650	103	No rock struck.
Sec. 4, T. 27, R. 8 E	650	150	Till, 30 feet; gravel and sand, 40 feet; remainder rock, 80 feet.
Sec. 7, T. 27, R. 7 E	700	73	Water from sand below till.
Sec. 34, T. 27, R. 7 E	760	185	No rock; mainly blue till.
Sec. 17, T. 27, R. 7 E	700	85	Schoolhouse well in sand below till.
Secs. 16, 17, 20, 21, T. 26, R. 8 E	800	100	Several wells 70 to 100 feet from sand below till.

MARSHALL COUNTY.

GENERAL STATEMENT.

Marshall County is situated on the borders of the Illinois River south of Bureau and Putnam counties. It has an area of 400 square miles, and Lacon is the county seat. About two-thirds of the county is situated east of the Illinois River and is mainly a plain standing about 300 feet above the river. Sandy Creek and Crow Creek lead westward entirely across this portion of the county, the former draining the north and the latter the south border. The portion west of the Illinois rises on the western border to an elevation fully 400 feet above the Illinois River, or about 850 feet above tide, there being a prominent morainic belt (the outer moraine of the Wisconsin series) traversing the western edge of the county from north to south.

The broad valley of the Illinois River, averaging about 5 miles in width, is filled to a depth of about 150 feet with gravel and sand. The well at Henry, on one of the terraces (not the highest), reached rock at 135 feet, and wells above this village in Putnam County strike rock at correspondingly low level The western portion of the county has a thin sheet of drift on the borders of the Illinois Valley, but there is a heavy deposit along the moraine. The eastern portion of the county is apparently heavily covered throughout, there being only occasional slight exposures of rock in the

east bluff of the Illinois River or along its tributaries. At Wenona, on the eastern border of the county, the drift is about 100 feet in thickness and is of similar depth at Toluca. These are the only points at which the distance to rock in that part of the county has been ascertained.

But few records of wells were obtained in this county, only a hasty reconnaissance having been made. Nothing was learned to indicate that wells are difficult to obtain.

INDIVIDUAL WELLS.

At Henry wells are usually obtained at a depth of 60 or 70 feet in the sand of the Illinois River bottom. But a few reach a depth of 100 or 110 feet. An artesian well 1,300 feet in depth obtains a "white sulphur" water in its lower part, probably either from the Lockport (Niagara) or Galena limestone. The drift at this well is 135 feet in depth. The discharge of the well is estimated at 32 gallons per minute from a pipe 3½ inches in diameter

At Lacon wells are usually obtained in the sand of the Illinois River Valley at a depth of about 60 feet, though on a higher terrace in the east part of the village a depth of about 100 feet is reached. It is reported that some of the wells in the lower part of the city strike a limestone at about 60 feet, but no very authentic data could be obtained. The Manual of American Waterworks reports that the public water supply is from a well, depth not given.

The public water supply at Wenona is obtained from a well 1,854 feet in depth which is reported by residents to have entered the Potsdam near the bottom, but perhaps terminated in St. Peter sandstone. It has a head 120 feet below the surface, or 565 feet above tide. The capacity is estimated at 100 gallons per minute. Strong wells are obtained from the drift in the vicinity of Wenona at depths of 40 to 60 feet. The drift in that vicinity, as already noted, is about 100 feet in depth.

At Toluca the coal shafts encounter a large amount of water in the lower part of the drift and also in the sandstones of the Coal Measures. It is proposed to utilize the water from one of these horizons as the public supply, but at last reports (in 1897) the waterworks had not been constructed.

WOODFORD COUNTY.

GENERAL STATEMENT.

Woodford County is situated on the east side of the Illinois River, immediately south of Marshall and Lasalle counties, and has an area of 540 square miles, with Metamora as the county seat. The northwestern portion is directly tributary to the Illinois River, through small streams. The remainder of the county is tributary to the Mackinaw River, which crosses its southeast border.

This is one of the most elevated counties of central Illinois, the uplands being in places about 850 feet and generally 750 feet or more above tide. The Illinois River, on the west border of the county, is only about 430 feet above tide, thus making a valley fully 400 feet in depth. The small streams, therefore, leading down to the valley make very rapid descent. The southwestern border of the county is crossed by the Bloomington morainic system, which has a subdued expression and rises so gradually from the plain on the east that it would scarcely attract notice, though it stands about 50 feet higher than the plain.

There is a heavy deposit of drift covering the entire county, if we may judge from the outcrops and the few wells which have reached rock, the thickness at Metamora being 280 feet, at Eureka 150, and at Minonk about 125 feet. Outcrops of rock are reported in a few places in the south part of the county on tributaries of Mackinaw River, and a single outcrop occurs on Panther Creek in the northwest part. So far as known to the writer there are no outcrops in the Illinois River bluffs.

INDIVIDUAL WELLS.

The public water supply for Minonk is obtained from a well 1,755 feet in depth, which has a head about 150 feet below the surface, or 600 feet above tide. Water veins are encountered in the Eocarboniferous limestone at about 750 feet, but a supply with greater head and volume was obtained in the lower part of the well, at about 1,700 feet, perhaps, from the St. Peter sandstone, no careful record being available. The water is moderately hard and the well has an estimated capacity of 100 gallons per minute. An abundance of water is obtained from the drift in this vicinity from a depth of 65 feet downward, rock usually being struck at about 125

feet. A record of the M. T. Ames coal shaft at Minonk shows yellow and blue tills to a depth of 62 feet, beneath which a harder till is entered, which is interbedded with sand.

At Elpaso the strongest wells are obtained, at about 115 feet, from sand beds in the drift. The public water supply is obtained from such wells.

The strongest wells in Eureka are found in beds of sand and gravel at a depth of 60 to 100 feet. The waterworks are supplied from wells of this class 60 feet in depth. Private wells are often obtained at depths of but 15 feet. The following detailed record of a prospect boring for coal at this town will serve to indicate the complexity of the drift beds. It is a copy of a sworn statement made to the coal company by G. W. Darling, who did the drilling:

Section of prospect boring for coal at Eureka, Illinois.

		Feet.
1.	Top soil had been removed.	
2.	Hardpan	8
3.	Blue clay and gravel	4
4.	Bowlders and large stones	2
5.	Coarse loose gravel and water	5
6.	Dark clay	2
7.	Variegated clay, different colors, with gravel	8
8.	Bowlders bedded in clay	6
9.	Cement gravel	41
10.	Very soft sand rock	3
11.	Quicksand, some water	2
12.	Coarse gravel	1
13.	Clay and gravel	24
14.	Drift formation, gravel and sand	1
15.	Wood drift	1
16.	Different colored clay with some stone	43
17.	Soft soapstone	12
18.	Hard blue soapstone	37
19.	Black shale	3½
20.	Coarse coal and sulphur	0½
21.	Good coal (splendid coal)	2
22.	Coal débris (or horseback)	1½
23.	Soapstone	9
24.	Limestone	1½
25.	Soapstone	3½
26.	Limestone	2½
27.	Soapstone	7
28.	Conglomerate rock, composed of sulphur, lime, flint, and iron	3
29.	Soapstone	47
30.	Blue hard slate	9¾
31.	Black slate, rather soft	1½
32.	Hard coal	3.1
33.	Fire clay	0$\frac{1}{12}$
34.	Soapstone	0¼

At Metamora strong wells are obtained at about 75 feet. A few wells in the vicinity of this town have been sunk to greater depths and some of them pass through a black muck containing wood under the blue till at a depth of about 140 feet. This muck and associated sand is in some cases 15 feet in thickness. A thin bed of blue clay underlies it, beneath which is a hard gray till, which in a single boring, reaching the rock, was 115 feet in depth.

STARK COUNTY.

GENERAL STATEMENT.

Stark County is situated west of Marshall and has an area of 290 square miles, with Toulon as the county seat. It is drained by the two headwater forks of Spoon River, which lead southward through it and unite just below the county line. The original drift surface was probably nearly plane, but has been much eroded by the streams, for this county lies outside the limits of the Wisconsin and probably of the Iowan sheet of drift, and in consequence has been subjected to erosion for a longer period than counties to the east.

The surface of the county is capped with loess to a depth of about 15 feet, beneath which is a deposit of glacial drift seldom more than 50 feet deep and in many places but 10 or 15 feet. Wells are ordinarily obtained in the drift, but a few obtain water in the rock at moderate depths.

INDIVIDUAL WELLS.

At Toulon and in that vicinity rock is entered at about 30 feet and water is usually obtained near the base of the drift.

In the vicinity of Wyoming many of the wells encounter a bed of muck or peat at a depth of 20 to 24 feet. This is said to be overlaid by a blue clay, but opportunity has not been afforded for determining whether it is a glacial deposit or a part of the loess. The wells are usually obtained in sand beneath this peat.

In the vicinity of Stark, on a low plain in the south part of the county, about 40 feet below the general level of the upland, wells reach a depth of 40 feet or more without entering rock.

PEORIA COUNTY.

GENERAL STATEMENT.

Peoria County is situated on the west side of the Illinois River, immediately south of Stark and western Marshall, and opposite Woodford and Tazewell counties. It has an area of 615 square miles, and Peoria is the county seat. The principal stream crossing the county is Kickapoo Creek, which has two forks, one of which drains the northern and the other the western portion of the county. The stream enters the Illinois just below the city of Peoria. The other direct tributaries of the Illinois are very small. Spoon River crosses the extreme northwest corner of the county in a westward course and flows through Knox and Fulton counties before joining the Illinois River.

The northeastern part of the county is occupied by two bulky morainic systems, the Shelbyville and Bloomington. West from these moraines the uplands are generally plane and stand about 100 feet lower than the main crests of the morainic systems. Like the neighboring portion of Stark County, this plane is covered with loess to a depth of 12 to 15 feet. The morainic ridges to the east are in places nearly destitute of loess, so that surface bowlders are a conspicuous feature. There are other portions of the moraines, however, which carry a deposit of loess-like silt 5 or 6 feet in depth. The sheet of loess which covers the plain west of the moraines passes under them, as indicated on a previous page (p. 187). The thickness of the drift in Peoria County is similar to that of Stark, except that the Illinois Valley and the moraine in the northeastern part of the county each have a very heavy drift deposit, 150 to 200 feet or more in thickness.

The drift usually contains a sufficient amount of sand and gravel at moderate depths to afford water for wells, and in places the entire drift section appears to be composed of sand and gravel. The majority of exposures along Kickapoo Creek are largely of this material, there being but a small amount of till exposed. In the morainic ridges in the northeast part of the county much till is usually found in wells. Excellent exposures of the till are to be seen along the Santa Fe Railroad in its descent to the Illinois Valley between Edelstein and Chillicothe.

INDIVIDUAL WELLS.

In the vicinity of Princeville, in the northern part of the county, wells obtain water in limestone at depths of 20 to 50 feet, but at Monica, only 4 miles west, 100 feet of drift is penetrated, and at Dunlap, 6 miles southeast, wells occasionally pass through 200 feet of drift. The drift appears to have built up an eroded country to a level about even with the tops of the rock ridges. Occasionally a rock ridge rises slightly above the general level, an instance being found in secs. 4 and 5, T. 11, R. 7 E., about 4 miles northeast of Princeville, where the rock appears at the top of a ridge standing 40 feet higher than Princeville Station.

Records of several deep wells made near Dunlap and Alta have been obtained from the driller, Mr. Alexander Lutcavish. In the village of Dunlap several wells obtain a strong supply of water at 110 to 112 feet without entering the rock. Nearly all the wells find a weak vein at 65 to 70 feet, which is apparently at the base of the Wisconsin till sheet. Occasionally strong wells are obtained at this depth. A well at Harrison Harlan's, 2 miles south of Dunlap, and at an altitude about 50 feet lower than the village, obtains water from sand and gravel at a depth of 117 feet. It is mainly through a stony blue clay. At William Rodgers's, 1½ miles west of Dunlap, on the crest of the Shelbyville moraine, at an altitude about 50 feet above the village, a well reaches a depth of 150 feet without entering rock. Another well at Mr. Powers's, also on the crest of the moraine, about a mile south from Mr. Rodgers's, is of similar depth, and also fails to reach rock. A well on "Jubilee Mound," about 5 miles west of Dunlap, 45 feet in depth, passes through 30 feet of yellow till and then enters a very hard blue till containing large bowlders. Blasting was necessary to remove this blue till. This mound is outside the limits of the Wisconsin drift. Mr. Lutcavish made a boring for John Holmes, sr., one mile east of Alta, which reached a depth of 370 feet, and apparently did not strike rock. Its lower portion was in a sand too fine to be screened by a pump strainer. A bed of muck with wood and leaves was passed through at a depth of 245 to 247 feet. This well is near the crest of the main ridge of the Bloomington morainic system, at an altitude nearly 400 feet above the Illinois River. At the farm of John Holmes, jr., one-half mile west of Alta, a well was obtained at a depth of 125 feet, which has 80 feet of water. Mr. William

Dickison has a well on the crest of the Shelbyville moraine, 2½ miles west of Alta, which was dug to a depth of 156 feet. It entered blue till at less than 10 feet and continued in it to a depth of 117 feet, when a thin bed of very bowldery clay was encountered, which apparently marks the base of the Wisconsin drift. Beneath this clay is a deposit of loess several feet in depth which connects with the surface loess of the districts to the west outside the limits of the Wisconsin drift. Beneath the loess is a hard till (Illinoian) alternating with beds of sand. Water is obtained in gravel near the bottom of the well and rises only to 20 feet. Mr. John Miller made a well 4 miles north of Dunlap which obtained water from sand and gravel at a depth of 218 feet. The upper 68 feet is evidently Wisconsin drift, while the remainder is Illinoian. The drift is almost entirely till. A well was made for Mr. Patrick Hogan about 4 miles south of Alta which reached a depth of 330 feet. Whether it entered rock was not ascertained. The well is on the crest of the Shelbyville moraine, at an altitude about 375 feet above the Illinois River.

In Elmwood and vicinity, in the west part of the county, wells are usually obtained at 25 to 40 feet. The drift in that vicinity is about 60 feet in depth. The Manual of American Waterworks reports that the public water supply is from an artesian well, depth not given.

At Peoria the public water supply is obtained from a large well 32 feet in diameter and 50 feet in depth, sunk in the low bottom of the Illinois River just above the city. The well passes through a bed of blue till and obtains water from gravel near the bottom. The city engineer, Mr. J. A. Harman, reports that the well will supply 8,000,000 gallons per day, even in dry seasons. It is thought that the bed of blue till overlying the water-bearing gravel protects the water from contamination by access of Illinois River water, or at least there is a probability that any water entering this gravel from the Illinois River passes through a sufficient amount of sand and gravel before reaching the well to insure the absorption of much of the impurities. Mr. Harman states that this water is preferable to water obtained from the underlying rock strata, for the latter water in this vicinity is brackish. Several deep wells have been sunk in the city at the distilleries, stock yards, and by private parties. One of these wells, controlled by D. L. Bigham, is used to supply the bath house on Adams street, between Hamilton and Fayette. This well penetrated 151 feet of glacial drift, and similar

depths have been found in other wells in the valley at this city. They show the rock floor to be at an altitude of 350 feet, or 80 feet below the Illinois River. Possibly a deeper portion of the old valley is to be found farther east, as these wells are all situated near the west bluff.

Between Peoria and Chillicothe, on a sandy terrace of the Illinois River, standing about 100 feet above the present stream, several wells have been sunk to depths of 90 to 120 feet. They apparently obtain water at about the level of the Illinois River. A few wells on this terrace near the west bluff obtain water at 50 to 75 feet.

The Manual of American Waterworks reports that the public water supply at Chillicothe is from driven wells, depth not given.

KNOX COUNTY.

GENERAL STATEMENT.

Knox County is situated in western Illinois immediately west of Stark and Peoria counties. It has an area of 720 square miles, and Galesburg is the county seat. The southeastern portion of the county is crossed by Spoon River in a southwestward course, and about three-fourths of the county is tributary to that stream. The northwest one-fourth of the county drains directly westward to the Mississippi River through Pope Creek and two branches of Henderson River. The county has a good surface drainage, the drainage systems being well matured and the slopes between streams sufficiently rapid to insure the discharge of water not absorbed by the soil. The loess, which forms a capping about 15 feet in thickness, is sufficiently porous to readily absorb a large part of the rainfall and return it to the crops in seasons of drought.

The glacial drift is generally but 20 or 30 feet in depth, but in places where valleys have been filled the depth may reach 100 feet or more. The average of 10 borings which enter rock is found to be 35 feet, and this is thought to fairly represent the upland average for the county. The majority of wells are obtained in the drift, some being sunk only to the base of the loess. The strong wells, however, usually penetrate the glacial drift a short distance.

INDIVIDUAL WELLS.

At Galesburg the public water supply is obtained in part from wells in the drift and in part from deep wells sunk to the St. Peter sandstone. The

wells in the drift are located along a valley leading westward from the town, and are sunk to depths of 70 or 80 feet without entering rock. They are mainly through sand, and the water rises nearly to the surface. A well was sunk in 1896 to a depth of 1,226 feet, entering St. Peter sandstone at 1,060 feet. The well is cased to the St. Peter and the entire depth penetrated in this formation is thought to be a water-yielding rock. The water has a temperature of 60° F. The head is 102 feet below the surface and 635 feet above tide, as determined by careful measurements conducted by the city engineer. The capacity is estimated at 120 gallons per minute. As this is but one-eighth the amount needed by the city, the drift wells furnish the greater part of the supply. It is planned to sink other deep wells in order to dispense with the water from the drift, since that is not entirely above suspicion of surface contamination. Many private wells in this city are obtained from sand below loess and till at depths of 25 to 45 feet. The drift is said to be 80 or 90 feet in depth for a distance of 5 or 6 miles northeast from Galesburg, but within a short distance in other directions rock is found at much shallower depths.

At Knoxville the public water supply is obtained from a well 1,350 feet in depth, which was sunk in 1896. It enters St. Peter sandstone at 1,180 feet and continues in that formation to the bottom. The well is cased to the top of the St. Peter sandstone in order to shut out sulphurous water struck at higher levels. It has an estimated capacity of 80 gallons per minute. The water has a temperature of 68° F. Private wells are obtained in the vicinity of Knoxville at depths of 20 to 40 feet, either near the base of the drift or in the underlying Coal Measures.

At the villages of Wataga, Oneida, and Altona coal shafts usually enter rock at about 30 feet, but wells are obtained near the base of the drift or only occasionally from the rock.

At Williamsfield, in the east part of the county, wells are usually obtained at shallow depths in the glacial drift, seldom exceeding 40 feet. The record of a well about 1½ miles west of this village is found to show 85 feet of drift without entering rock. The cuttings along the Santa Fe Railway between Williamsfield and Dahinda expose a complex series of sand and till beds in the descent to Spoon River. Wells on the bordering uplands appear to penetrate a similar complex series.

At Yates, in the southern portion of the county, Coal Measures shale

is entered at about 30 feet, but wells are usually obtained without entering the rock. A drift ridge leading east from this town and standing 30 or 35 feet above the general level of the plain is found to have a black soil beneath till at about the level of its base. This soil has been struck in several wells.

At Abingdon wells are usually obtained from rock at depths of only 25 or 30 feet. The drift is in places but 15 feet in thickness.

WARREN COUNTY.

GENERAL STATEMENT.

Warren County is situated immediately west of Knox and has an area of 540 square miles, with Monmouth as the county seat. The drainage is mainly westward through Henderson River and other streams into the Mississippi. The southeastern portion of the county, however, drains eastward to Spoon River. The features of this county are very similar to those of Knox, there being a well-drained surface and comparatively thin covering of drift. The loess is fully as thick as in Knox County and equally pervious to water. At the base of the loess numerous springs are to be seen where it outcrops along the sides of ravines.

INDIVIDUAL WELLS.

At Monmouth the public water supply is from two wells, each about 1,227 feet in depth. They enter the St. Peter sandstone 156 feet. One was cased to the top of this sandstone, but the other was not cased to so great a depth, for the reason that a water vein was found at a depth of about 935 feet which seemed desirable to admit to the well. The head in the well cased to the St. Peter sandstone is 60 feet below the surface and 675 feet above tide. No data have been obtained concerning the head in the other well. The capacity of the first-named well is estimated at 200 gallons per minute. An analysis of its water appears in the Seventeenth Annual Report of this Survey.[1] Private wells of considerable strength are obtained in the vicinity of Monmouth at a depth of about 60 feet, in some cases from the glacial drift. There are also shallower wells of less strength.

[1] Part II, p. 827.

In the southeast part of the county rock is often struck on the high points at 25 feet or less, but on lower ground the drift is usually thicker. In the southwest part of the county the drift appears to have an average depth of at least 50 feet, and wells seldom reach the rock.

The Manual of American Waterworks (1897) reports that waterworks systems have recently been introduced at Alexis, Kirkwood, and Roseville. In each village the supply is from a well. That at Kirkwood is reported to be insufficient for the needs of the village.

HENDERSON COUNTY.

GENERAL STATEMENT.

Henderson County borders the Mississippi River in the western part of the State, immediately west of Warren and south of Mercer County. It has an area of 380 square miles, and Oquawka is the county seat. The county is drained mainly by Henderson River and its tributaries, which lead westward to the Mississippi. The southern portion is tributary to Honey Creek, which leads westward entirely across the county.

There is a strip of the Mississippi bottoms along the west border of the county having an average width of about 5 miles, much of which is subject to overflow and is sparsely settled. The remainder of the bottom land is very sandy. The uplands, which stand about 200 feet above the river, are covered with loess to a depth of 20 feet or more. In places the loess has been heaped into dunes and ridges on the brow of the bluffs, which stand 50 feet or more above the uplands to the east. In places also sand in dunes appears along the brow of the bluff.

But few records of wells have been obtained in this county, and these indicate considerable difference in the distance to rock, there being a range from 20 feet to over 150 feet. The rock floor of the Mississippi Valley probably stands nearly 150 feet below the level of the bottoms, its elevation at Fort Madison, Iowa, just beyond the limits of this county, being 360 to 370 feet above tide, or about 140 feet below the level of low water at that city. Preglacial tributaries of this valley would be excavated to a correspondingly low level; hence we may expect to find a drift filling of not less than 300 feet on the portions of the uplands adjacent to the Mississippi, where the valleys have been filled to the level of the upland plain.

INDIVIDUAL WELLS.

At Oquawka wells are obtained by driving pipes to a depth of 40 to 60 feet in the sand of the Mississippi bottoms, and wells of this class are common throughout the settled portions of these bottoms.

In the vicinity of Biggsville rock is entered on the uplands at a depth of about 40 feet, but wells are usually obtained at 12 to 30 feet. Similar conditions prevail in the vicinity of Media and Stronghurst, though the drift occasionally exceeds 50 feet.

Near Decorra, in the southwest part of the county, several wells have been sunk to depths of 90 to 150 feet. They usually enter rock within 100 feet of the surface. About 2 miles southeast of Decorra rock is struck in several wells at only 30 feet.

At Stronghurst a deep well was drilled by the Stronghurst-Media Company in the winter of 1897–98 with a view to obtain oil. Instead water was obtained, which rises to within 30 feet of the surface, or 643 feet above tide. The log of the well kept by the drillers, Wilson Brothers, of Belleville, Illinois, is as follows (names in parentheses are by the writer):

Section of an oil boring at Stronghurst, Illinois.

	Feet.
1. Glacial drift, largely blue clay	150
2. Gray shale (Kinderhook?)	165
3. Limestone (Devonian and Upper Silurian?)	105
4. Shale (Hudson River Group?)	165
5. Gray limestone (Trenton?)	200
6. Brown limestone (Trenton?)	15
7. Gray limestone (Trenton?)	60
8. Sandstone (St. Peter?)	71
9. White shale	25
10. White limestone	10
11. White shale	5
12. White limestone	24
13. White sandstone	20
14. Limestone	50
15. Shale	5
16. Limestone	105
17. Sandstone	5
18. Limestone	25
19. St. Croix (?) sandstone	290
20. Sandstone	6
Total	1,601

There was a strong yield of water in the Trenton and in the sandstone strata at lower depths.

HANCOCK COUNTY.

GENERAL STATEMENT.

Hancock County borders on the Mississippi below Henderson County and opposite the extreme southeast corner of Iowa. It has an area of 769 square miles, and Carthage is the county seat. Although bordering the Mississippi River, a considerable portion of the county is tributary to the Illinois River. In the north part of the county the divide between the Illinois and Mississippi rivers is only 3 or 4 miles from the east bluff of the Mississippi. The principal stream leading to the Illinois in this county is Crooked Creek, which drains the northeastern fourth of the county. The principal stream tributary to the Mississippi is Bear Creek, which drains the southwestern fourth of the county southward into Adams County and thence westward into the Mississippi. Along much of the northern half of the border of this county the Mississippi River is in a new course and occupies the entire width of its valley. The distance between bluffs is but little more than a mile. In the remainder of the border the river is in a preglacial course, with bottoms 6 or 8 miles in width. These bottoms are mainly on the Missouri side, though near the south line they extend 3 or 4 miles into this county. The uplands stand 150 to 200 feet above the river and are generally plane. There is, however, a well-defined drift ridge leading southward from Warsaw a short distance east from the river bluff, a ridge which, as previously described, apparently marks the western limit of the Illinois glacial lobe.

The thickness of the drift varies greatly, owing to the presence of deep preglacial valleys which have been filled to a level as great as the bordering uplands. In such valleys rock is not usually entered at less than 200 feet, but on the bordering uplands it may be entered at 20 feet. There is usually, however, 50 or 60 feet of drift on the preglacial uplands. One of the most conspicuous of these buried valleys revealed by the wells is found in the central portion of the county, near Carthage, and a portion of its course is along the present water parting between the Illinois and the Mississippi rivers. This valley apparently leads southward into Adams County along a line a short distance east of the valley of Bear Creek. Perhaps its lower course is followed by Bear Creek.

The drift is mainly a compact till, and in places wells are difficult to obtain. A large number of wells have been sunk to a depth of 100 to 200

feet, or even more, many of them entering limestone before obtaining a strong vein of water.

A portion of the Illinois-Mississippi divide is flat and poorly drained, but the portions of the county adjacent to the Mississippi, and also to Bear Creek and to Crooked Creek, are greatly eroded.

INDIVIDUAL WELLS.

At Dallas, on the northern border of the county, in the Mississippi Valley, wells are usually obtained at 20 to 35 feet, mainly in limestone. Occasionally they are sunk to a depth of 150 feet.

At Nauvoo, on the brow of the Mississippi bluff, in the northwest part of the county, the wells are usually obtained at about 20 feet, in sand. Rock is entered at 25 to 30 feet, but wells seldom reach it.

At Laharpe, on the upland plain, in the northeast part of the county, the strong wells are obtained in sand below till at a depth of about 60 feet. One well made by Mr. Bainter enters rock at 100 feet.

In the vicinity of Webster and Fountain Green, in the east part of the county, wells 50 feet in depth do not reach rock. They are mainly through till. Between these villages and Laharpe there is an area of several square miles in which the rock is so near the surface that sink holes abound.

At Carthage the public water supply is obtained from two deep wells, one of which terminated in the St. Peter sandstone at 1,000 feet, but the other continued to a depth of 1,700 feet. Water veins are struck in the Niagara limestone at about 750 feet; in the Galena limestone at 865 feet, and in the St. Peter sandstone at 975 feet. The head is about 16 feet below the surface, or 660 feet above tide. The water is rather unpleasant on account of salinity. The following record of strata penetrated by one well before reaching the St. Peter is taken from the Geology of Illinois:[1]

Section of deep well at Carthage, Illinois.

	Feet.
Drift, clay, sand, and gravel	214
White limestone	70
Shale	355
Limestone	336
St. Peter sandstone, penetrated	25
Total depth	1,000

At Elvaston wells are obtained at 12 to 16 feet, and also at 20 to 30 feet, from beds of gravel associated with till.

[1] Vol. VIII, p. 65.

At Hamilton, on the brow of the Mississippi bluffs, in the west part of the county, the best wells are obtained in the rock, which is entered at 20 or 30 feet. Many weak wells, however, are obtained from the drift. An artesian well has been sunk at Ringland's Sanitarium, in the north part of the village. It has a depth of 680 feet and obtains a flow from the Lockport (Niagara) limestone, which is penetrated about 25 feet. The head is reported to be 63 feet above the surface, or about 660 feet above tide.

At Warsaw several artesian wells have been sunk, one by the village and others by corporations and private individuals. The village well is mainly for fire protection. Gen. Oliver Edwards, of Warsaw, has furnished the Survey a carefully prepared body of statistics concerning the wells, and these statistics are presented in the discussion of artesian wells in Illinois appearing in the Seventeenth Annual Report of this Survey. The wells all terminate in the Galena or Trenton limestone and have depths ranging from 750 to 860 feet. The original head at each of the wells was about 680 feet above tide, but at present it scarcely exceeds 600 feet. The water is sulphurous, but otherwise not of unpleasant quality.

At Plymouth, in the eastern part of the county, it is proposed to obtain a public water supply from an artesian well.[1]

At Augusta, in the southeast corner of the county, wells are usually obtained in sand contained in the drift, at depths ranging from 20 to 60 feet. A few have been drilled into the underlying Coal Measures to depths ranging from 120 to 265 feet.

The following table embraces the deepest wells, not reported in the above discussion, of which records were collected. They are confined mainly to the southern half of the county:

Wells in Hancock County.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Sec. 11, T. 4, R. 9 W	645	73	Loess and yellow till, 25 feet; blue till, 48 feet; no rock.
Sec. 12, T. 4, R. 9 W	620	50	Enters rock at 45 feet.
Sec. 12, T. 4, R. 9 W	625	80	No rock; mainly sandy drift.
Sec. 7, T. 4, R. 8 W	660	45	Rock entered at 40 feet.

[1] Manual of American Waterworks, 1897.

Wells in Hancock County—Continued.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
W. McCuen, 4 miles south of Hamilton.	690	74	Loess, 12 feet; grayish-yellow gummy clay, 22 feet; blue till, 8 feet; peaty soil with wood, 5 feet; blue till, 28 feet.
Sec. 30, T. 4, R. 8 W	750	60	No rock; mainly gray till.
Sec. 31, T. 4, R. 8 W	710	63	Rock entered at bottom.
Sec. 31, T. 4, R. 8 W	750	42	Surface silt, 10 feet; brown clay, few pebbles, 15 feet; yellowish-gray till, 17 feet.
Sutter and vicinity	690	40	Rock entered at about 25 feet.
Tioga and vicinity	700	40	Surface silt, 8 to 10 feet; yellow till, 20 to 25 feet; sand, 5 feet.
J. D. Wood, at Chili	670	70	Yellow and brown clays, 15 feet; gray gummy clay, 10 feet; yellowish-gray till, 40 feet; hard blue till, 20 feet; rock at bottom.
Mr. Cunningham, 2 miles northeast of Chili.	670	• 80	Two wells enter rock at 75 or 80 feet.
Mr. Dickerson, 2 miles north of Chili.	680	220	Surface silt, 6 feet; grayish gummy clay and yellow till, 34 feet; blue clay with few pebbles, 160 feet; gray sand, 10 feet; cemented gravel, 5 feet; loose gravel, 5 feet.
Bowen and vicinity	690	70	Several wells enter rock at 65 or 70 feet; drift mainly till.
Owens's mill at Stillwell	670	217	Rock entered at 207 feet.
Sec. 1, T. 3, R. 7 W	670	198	Yellowish clays, 20 feet; blue clay, 175 feet; sand, 3 feet.
Sec. 36, T. 4, R. 7 W	660	192	Yellow clay, 20 feet; blue clay, 168 feet; sand with wood, 4 feet.
East part T. 4, R. 6 W	660	40	Rock entered at 30 or 40 feet.
Sec. 4, T. 4, R. 6 W	670	75	Rock at about 75 feet.
Secs. 15 and 16, T. 4, R. 6 W	680	100	Rock struck at about 100 feet.
Sec. 20, T. 4, R. 6 W	690	195	Silt and yellow clay, 26 feet; blue clay, few pebbles, 169 feet; sand at bottom, 6 feet.
Sec. 29, T. 4, R. 6 W	700	1,030	The well enters rock at 200 feet and terminates in St. Peter sandstone; water rises to 40 feet below surface.
Sec. 28, T. 4, R. 6 W	700	100	Rock at about 100 feet.
Gittings Mound, north line of county.	750	41	Yellow till, 30 feet; blue till, 11 feet; sand at bottom.

McDONOUGH COUNTY.

GENERAL STATEMENT.

McDonough County is situated east of Hancock and has an area of 540 miles, with Macomb as the county seat. The county is drained almost entirely by Crooked Creek, through several tributaries leading southwestward to that stream. The surface is generally much eroded, but there is a flat strip on the north and east borders in which drainage is rather imperfect. The county is covered to a depth of 8 to 12 feet or more with a porous sheet of loess which absorbs water rapidly and returns it to the crops in seasons of drought.

The drift is composed largely of a compact till, and in places strong wells can not be obtained in it. Throughout much of the county, however, the wells do not enter the rock. There is apparently a general coating of 50 to 75 feet of drift, and in places a much greater depth. In the extreme northeast corner, however, near Prairie City, the rock rises in ridges slightly above the general level of the upland plain.

INDIVIDUAL WELLS.

At Prairie City wells on the rock ridges are sunk to depths of 50 feet or more; those on the plane tracts obtain water in the drift at 20 to 30 feet.

At Bushnell the public water supply is obtained from a well 115 feet in depth which does not enter rock. A well at the Toledo, Peoria and Western Railway station enters rock at 140 feet. The drift consists of about 20 feet of loess and yellow till, beneath which is a heavy sheet of blue till. Wells are obtained from thin beds of sand and gravel in the blue till, or occasionally at the top of the till.

At Macomb the public water supply is obtained from a well 1,630 feet in depth. The well is cased to the St. Peter sandstone, which is entered at 1,135 feet, and the entire supply is from that sandstone. An analysis made by this Survey is published in the Seventeenth Annual Report (Part II, pp. 925, 926). The water is moderately hard, but its chief mineral ingredients are sodium chloride and sodium sulphate. Some dissatisfaction with the use of the water is felt because of these ingredients, though the quality is similar to that of the water from several other wells in use in western Illinois. The drift at Macomb has a known range of nearly 100 feet in

depth. The deep well penetrates 145 feet, but in parts of the city at similar altitude rock is entered at only 60 feet.

At Adair the wells are usually 25 or 30 feet in depth, though they occasionally pass into the rock, which is entered at about 50 feet. The drift is mainly blue till, which is entered at only 10 or 12 feet from the surface.

At Good Hope the village well is 33 feet in depth and has the following section, reported by Rev. S. D. Peet:

Section of town well at Good Hope, Illinois.

	Feet.
Loess	16
Pebbly brown clay	2 or 3
Sand with a few pebbles	9
Fine sand with ferruginous crust	2
Blue sand	2
Blue till	2

Wells in the vicinity of Good Hope enter rock at depths ranging from 45 to 86 feet, and are mainly through blue till.

FULTON COUNTY.

GENERAL STATEMENT.

Fulton County is situated east of McDonough and has the Illinois River on its eastern border. The area is 870 square miles, and Lewistown is its county seat. The principal stream traversing the county is Spoon River, which passes in a southward course through its western part. The surface, like that of the adjoining counties on the north and west, is well drained. In addition to the drainage lines, which carry off much of the surplus rainfall, there is a capping of porous loess which absorbs a large part of the rain and returns the water to the soil in seasons of drought.

The drift is in thickness similar to that in adjoining counties. An average of sections on the uplands reaching rock is 41 feet. In preglacial valleys the thickness is much greater, for the main valleys were cut to a level 75 feet or more below the low water of the present Illinois. The majority of wells are obtained without entering the rock, there being a sufficient amount of sand and gravel interbedded with the till to afford a strong supply of water for wells.

INDIVIDUAL WELLS.

At Farmington, in the northeast corner of the county, the drift is only about 20 feet in thickness and wells are frequently sunk to slight depth in

the underlying rock. Similar conditions prevail at the neighboring village of Fairview, and also at Avon, in the northwest part of the county. Fire protection is obtained at Avon and Farmington by pumping from wells to tanks.

The city of Canton obtains its public water supply from two deep wells, one of which reaches a depth of 2,500 feet and the other 1,646 feet. The latter terminates in the St. Peter sandstone, but the former may reach the Potsdam sandstone. Water is found in the Galena limestone at 1,100 to 1,300 feet, as well as in the St. Peter sandstone and lower strata. The deeper well, with a diameter of but 4 inches, has an estimated capacity of 125 gallons a minute. The shallower one, with a diameter of 6 inches, will yield 260 gallons a minute. The former well is cased only 90 feet and has a head 630 feet above tide, or about 30 feet below the surface. The latter well is cased 797 feet and has a head 615 feet above tide, which is 15 feet above the surface, this well being located on ground about 60 feet lower than the other. The following record of the strata penetrated by the shallower well was published in a Canton paper at the time of the completion of the well:

Section of a deep well at Canton, Illinois.

	Feet.
Surface	14
Blue shale	29
Gray shale	45
Blue shale	40
Coal	1
Fire clay	6
Blue shale	35
Gray shale	22
Coal	2
Slate	12
Shale	55
Limestone, sandstone, and shale	65
Shale	15
Black limestone	7
Limestone, flint, sandstone, shale, white marl	192
Shale	225
Limestone	63
Limestone and shale (mixed)	272
Trenton limestone (water bearing, flow)	265
Limestone, sandstone, shale, etc	100
St. Peter sandstone (water bearing, flow)	241½

In the above section the first 247 feet of rock should perhaps be referred to the Coal Measures; the next 279 feet are probably Eocarboniferous limestone, shale, etc.; the following heavy bed of shale (225 feet) is

presumably Kinderhook; the next 335 feet is probably to be referred to the Niagara and Hudson river formations; and the next 305 feet to the Galena and Trenton.

The public water supply for the city of Lewistown is obtained from a series of wells in Spoon River Valley about 20 feet in depth. The town is situated on an upland, probably 130 feet above the river, and the wells there are obtained from gravel in the glacial drift at a depth of 25 to 35 feet.

At Astoria, in the southern part of the county, wells are obtained at 20 to 40 feet from sand below till. The drift in that vicinity ranges from 30 to 70 feet in depth, and is largely till.

At Vermont, on the west border of the county, wells are usually obtained at 25 to 35 feet. The drift in the vicinity of that village is about 60 feet in depth. A test boring for coal, oil, etc., was made at this village to the depth of 2,487 feet, which probably reached the Potsdam sandstone, but the boring is not utilized for water.

At Ipava a well 1,570 feet in depth supplies the waterworks, and is used also by a woolen mill. A sulpho-saline water was struck, probably in the Galena, at a depth of 1,010 feet. A water of more pleasant taste is obtained from the St. Peter sandstone. Strong wells are obtained in the vicinity of this village, either from drift or from rock, at about 100 feet.

MASON COUNTY.

GENERAL STATEMENT.

Mason County is situated on the east side of the Illinois River opposite Fulton County, and has an area of 560 square miles, with Havana as the county seat. The county occupies a low basin-like expansion of the Illinois Valley, heavily covered with sand, except where old river channels have left a surface deposit of muck. The drainage is imperfect, and extensive artificial ditching has been necessary to render the old river channels productive. Much of the county is so sandy that it is not cultivated. The eastern portion, however, is very fertile, the sand there being a fine deposit approximating a loess.

The thickness of the drift is known only at a single point—Mason—where it is 204 feet. The wells are usually obtained at depths of 20 to 40 feet, but at Havana they are frequently sunk to a depth of 70 feet, through sand and gravel.

INDIVIDUAL WELLS.

At Mason the wells often reach a depth of 130 feet, though some water can be obtained at 35 feet. A prospect boring for coal at this town penetrated the following complex series of drift deposits:

Section of drift beds in a coal boring at Mason, Illinois.

	Ft.	In.
Black soil	5	0
Yellow clay	30	0
Yellow sand	5	0
Gray sand	32	7
Blue clay	1	0
Fine sand	22	11
Hardpan	15	6
Blue clay	7	0
Sand	11	0
Sand and gravel	20	0
Coarse sand	10	0
Sand and gravel	33	0
Fine red sand	0	4
Dark sand	1	8
Gravel and bowlders	5	4
Sand	3	8
Total drift	204	0

Several beds of coal were passed through in the underlying Coal Measures, the thickest being 34 inches, struck at a depth of 290 to 293 feet. The rock floor at this well is 394 feet above tide, the well mouth being 598 feet.

The public water supply at the city of Havana is reported by the Manual of American Waterworks to be obtained from 10 driven wells, 72 feet in depth and 6 inches in diameter.

Near San Jose, in the northeast part of the county, wells on the swampy land are obtained at about 30 feet. They penetrate 6 feet or more of black muck, beneath which they are in a fine blue sand to near the bottom, where gravel is struck. On the higher ground east from San Jose wells are frequently sunk to a depth of 100 feet or more, largely through sand and gravel.

TAZEWELL COUNTY.

GENERAL STATEMENT.

Tazewell County is situated northeast of Mason, on the east side of the Illinois River, and has an area of 650 square miles, with Pekin as the county seat. The county is traversed nearly centrally from east to west by

Mackinaw River, which enters the Illinois just below Pekin. The northern part of the county is drained by Farm Creek, which enters the Illinois opposite Peoria. About one-fourth of the county is situated in the Illinois River valley, in the northward continuation of the basin referred to in the description of Mason County. The uplands have an extreme altitude of about 450 feet above the Illinois River and a general elevation of nearly 300 feet. The Bloomington morainic system crosses the northeast part of the county and the Shelbyville or outer moraine of the Wisconsin drift leads northwestward through the central portion. Between these moraines there is a narrow plane tract scarcely 5 miles in average width. The portion outside the Wisconsin drift is mainly within the valley of the Illinois River, but a narrow strip of upland is found between the moraine and river bluff south from Pekin.

There are rock outcrops at a few points along the east bluff of the Illinois River, but the well borings distributed widely over the county indicate that the drift is a heavy deposit. Twenty borings which do not reach rock have an average depth of 135 feet, while four which reach rock penetrate an average thickness of 247 feet of drift. It is probable that the average for the county is not less than 200 feet.

In the Illinois Valley the drift is largely gravel and sand, but on the uplands there is a heavy sheet of soft blue till deposited at the Wisconsin stage of glaciation. The deep wells frequently enter a hard till near the bottom, which is presumably the deposit of an earlier stage of glaciation, and contemporaneous with the sheet of drift found outside the limits of the Wisconsin drift. Wells are often obtained at depths of but 25 or 30 feet, and the depth rarely exceeds 75 feet.

INDIVIDUAL WELLS.

The public water supply of Washington is obtained from wells driven in the drift to a depth of 50 feet or more, the supply coming from sand below till. This sand is usually entered at about 30 feet. A well at Andrew's mill, in Washington, 227 feet in depth, is thought to have entered rock 2 feet. There was a change from soft to hard till at about 150 feet. A well at the Milburn stock farm, near Washington, 236 feet in depth, did not reach rock. It was mainly through till. Some inflammable gas was encountered near the bottom. A well at William Kiel's, about 4 miles west

of Washington, reached a depth of 262 feet without entering rock. Several changes in structure were noted during the boring.

At Morton the waterworks well is 230 feet in depth and terminates in sand. Three other wells within 2 miles northwest reach about the same depth without entering rock, and have similar sections. The waterworks well is reported to have penetrated 30 feet of yellow clay and sand at surface, beneath which was 70 feet of soft blue till, belonging apparently to the Shelbyville drift sheet. The next 100 feet is mainly a hard gray till, but includes about 20 feet of sand. The lower 30 feet is white sand.

At Pekin the public water supply is obtained from the gravel of the Illinois River Valley. A large well, 50 feet in diameter, is excavated to a depth of 30 feet, in the bottom of which several small wells are driven 50 feet farther. The wells will yield 3,000,000 gallons a day. Distilleries at this city use the Illinois River water. An artesian well sunk on a high terrace in the east part of the city at the City Park reached a depth of 850 feet, and struck salt water at about 500 feet. The well mouth is 100 feet above the level of the Illinois River, or 525 feet above tide, and a flow of water is obtained. The drift is about 200 feet in thickness. Within a half mile east of the well rock is exposed in the bluff at an altitude 25 feet higher than the well mouth.

At Delavan the public water supply is from a well obtained in sand and gravel at a depth of 160 feet. A well was sunk by this village to a depth of 241 feet without entering rock, and penetrated the following beds:

Section of a boring at Delavan, Illinois.

	Feet.
Yellow till	15
Blue till	60
Black muck with wood	6
Green mucky clay	8
Gray sandy till	30
Gray sand	122
Total depth	241

The muck found beneath the blue till is probably at the base of the Wisconsin drift sheet. A well 4 miles northeast of Delavan at an altitude about 80 feet above the village, or 700 feet above tide, struck rock at a depth of 313 feet. The drift was mainly till to a depth of 140 feet, and included a bed of black muck near the base. The remainder of the section is principally sand, as at Delavan.

In the vicinity of Green Valley village, on the portion of the Illinois bottoms northwest from Delavan, several wells have been sunk to a depth of over 100 feet through sand and gravel without entering rock. In one case a depth of 145 feet was reached. At the east border of the valley, however, the wells in some cases penetrate 40 to 60 feet of clay before entering sand and gravel. One in sec. 6, T. 22, R. 4 W. penetrated 60 feet of clay, then 75 feet of fine sand, and obtained water in the gravel at bottom. Another in sec. 7 of the same township penetrated 62 feet of clay and 30 feet of sand, when a water-bearing gravel was struck.

At Hopedale the railway well is 195 feet in depth without reaching rock. It was mainly through till to a depth of 160 feet, beneath which sand was encountered. A bed of black muck was passed through between till sheets, but the precise depth was not noted. Between Hopedale and Armington, a well on the farm of Robert Pratt, 250 feet in depth, is thought to have struck rock at the bottom. The well mouth is about 650 feet above tide.

At Mackinaw a boring 160 feet in depth was mainly through till to 140 feet, beneath which sand was entered which yields an inflammable gas. Wells at this village usually obtain water in sand and gravel between till sheets at a depth of 35 or 40 feet. The waterworks well is 65 feet deep, and is scarcely adequate to supply the village.

In the vicinity of Cooper, on the crest of the inner strong ridge of the Bloomington morainic system, at an altitude about 820 feet above tide, wells are frequently sunk to a depth of 150 feet, mainly through till. In some wells a black muck is found between tills nearly 150 feet below the surface.

McLEAN COUNTY.

GENERAL STATEMENT.

McLean County is situated east of Tazewell, with Bloomington as the county seat. It is the largest county in the State, its area being 1,166 square miles. The northern half of the county is tributary to the Mackinaw River, with the exception of a few square miles in the northeast corner, which are drained northward to the Illinois-Vermilion. The southern half is drained by the Sangamon and its tributaries. The valleys are all small, within the limits of the county, and in many cases are mere ditches cut to

a depth of but a few feet. The greater part of the county is, however, sufficiently drained to need but little artificial ditching.

This is one of the most elevated counties in central Illinois, much of its surface being more than 800 feet above tide and occasional points 900 feet. The northern border and also the southwest corner fall below 750 feet. A very small area in the southwest corner falls below 700 feet.

The Bloomington morainic system traverses the county nearly centrally in an east-west direction and occupies a belt 6 to 10 miles in width. The Mackinaw River drains its north border and the Sangamon and tributaries its south border. A small moraine, Cropsey Ridge, follows the north border of the Mackinaw River across the northeast part of the county, separating this drainage system from the Vermilion drainage system.

The drift is of great depth, averaging probably over 200 feet. Records of ten deep borings were obtained which reach rock at an average of 155 feet, but twenty-one others have an average depth of 174 feet without entering rock. The drift is apparently thinnest in the northern part of the county, where rock is struck at about 100 feet. The drift in the central and southern portions has a depth of 200 to 250 feet. Buried soils are found at two or more horizons at depths usually of 100 feet or more, but on the plain outside the morainic system a soil occurs at 40 feet or less. The drift above the first buried soil is usually a soft blue till. At greater depths the till is frequently found to be very hard, as in the neighboring counties to the north and northeast, already discussed. In some of the deep borings a large amount of sand and gravel is found in the lower part of the drift. Many wells have been sunk to a depth of 150 to 200 feet in order to reach the water-bearing beds beneath the blue till, there being only a small amount of water-bearing gravel interbedded with the blue till.

INDIVIDUAL WELLS.

At Chenoa, on the north border of the county, several strong wells have been obtained from depths of 100 to 150 feet near the surface of the Coal Measures sandstone. The public supply is from two wells 135 and 214 feet in depth.[1] Rock is entered at this village at about 80 feet. Wells from the drift are usually weak compared with those from the rock.

[1] Manual of American Waterworks, 1897.

The Waterworks Manual reports that Lexington has its public supply from a well, but the depth is not given.

At Colfax borings for coal entered rock at 100 to 125 feet, but wells are usually obtained at moderate depths, seldom exceeding 40 feet. The drift contains considerable sand in that vicinity. The record of a well about 4 miles west of Colfax shows scarcely any till in a depth of 115 feet, at which depth rock was entered.

The city of Bloomington obtains its water supply from a large well 60 feet in depth, located in the valley of Sugar Creek. The well penetrates about 33 feet of surface gravel, beneath which is blue clay and water-bearing gravel at 60 to 65 feet. Prospect borings show a belt of gravel about 2,000 feet in width leading down the creek valley from the vicinity of the waterworks. Except in seasons of extreme drought, such as that of 1894 and 1895, the waterworks well can be depended upon to furnish an adequate supply for the city. The coal shaft near the Chicago and Alton Railway station, at an altitude of about 750 feet, entered rock at a depth of 161 feet, penetrating the following drift beds:

Section of drift beds in a coal shaft in Bloomington, Illinois.

	Feet.
Loam and gravel	20
Blue till	61
Sand	4
Blue till	76
Total drift	161

In Vol. IV of the Geology of Illinois a coal shaft at Bloomington, one-half mile north of the Chicago and Alton Railway station, is reported to have penetrated 252 feet of drift, as follows:

Section in coal shaft one-half mile north of preceding.

	Feet.
Brown clay	10
Blue clay	40
Gravelly hardpan	60
Black mold with pieces of wood	13
Hardpan and clay	89
Black mold	6
Blue clay	34
Sand, buff and drab, with fossil shells	2
Total drift	252

A well in the east part of Bloomington 140 feet in depth is reported by the driller to have penetrated a "blue rock" the lower 40 feet. It is

possible, however, that the "blue rock" is only a hard till. A well at the Soldiers' Orphans' Home near Bloomington obtains water in gravel below till at 130 feet.

At Leroy, on a plain south of the Bloomington morainic system, strong wells are obtained in sand at a depth of 20 or 30 feet. In the vicinity of the village wells pass through a black muck at 35 to 40 feet. The public water supply is from a well 110 feet in depth and 8 inches in diameter, which will yield at least 100 gallons a minute. Many wells on farms in the vicinity of Leroy are sunk to depths of 75 or 100 feet, and occasionally 200 feet, without entering rock, and the water rises to within 50 feet of the surface, and occasionally within 10 feet. A prospect boring for coal at Leroy, made some years ago, was abandoned at a depth of 200 feet without entering rock.

At Saybrook, in the eastern part of the county, on the outer slope of the Bloomington morainic system, a prospect boring for coal reached rock at 247 feet. It was mainly through till for 38 feet, then mainly sand for 57 feet, beneath which was 100 feet of till, which was in turn underlain by 52 feet of sandy and gravelly drift.

The village of Danvers, in the western part of the county, has recently put in a waterworks system which obtains its supply from a well about 200 feet in depth which does not enter rock. The creamery well at Danvers is also about 200 feet in depth without entering rock. It is mainly through till, and struck an inflammable gas at about 170 feet. The village stands on the outer ridge of the Bloomington morainic system at an altitude slightly above 800 feet.

In the vicinity of Shirley and Funk's Grove the wells are reported by Mr. Lafayette Funk to have a general depth of only 30 or 40 feet, and rarely to exceed 80 feet. Water is obtained in gravel below till. The village well at Shirley has a depth of 40 feet, but a neighboring well at Mr. Douglas's residence reached a depth of 75 feet.

At Heyworth the general depth of wells is 30 to 40 feet, abundance of water being found in the gravel below the upper sheet of till. This village has sunk borings for gas which reach a depth of 155 to 300 feet. Gas is found in sand at 155 to 165 feet in a well about one-half mile south of the village, and at 214 feet in a well three-fourths of a mile south of the village. A well in the village 300 feet in depth obtained very little gas, though it is thought

to have reached the rock. The village is supplied with gas from a well southeast of it. This is reported by the owner, J. C. Wakefield, to have a pressure of 22 pounds to the square inch from a 2-inch pipe, and during the winter of 1896–97 it supplied fuel for 200 stoves. The gas may be derived in part from underlying Coal Measures shale, but muck beds inclosed in the drift afford a probable source. A section of the drift beds penetrated appears on page 215.

The wells in the following table are the deepest of which records were obtained, and include but a small part of those which have been sunk in the county. There is probably not a township in the county which does not include several wells over 100 feet in depth.

Wells of McLean County.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Mr. Helderley, near Carlock	775	210	Three beds of black clay, probably soil, the lowest at about 200 feet, separated by till, sand, and gravel; upper 90 feet of well entirely till.
Jacob Shad, 3 miles east of Carlock.	800	250	Black clay, probably soil, at about 150 feet.
Sec. 31, T. 24, R. 5 E	850	146	Inflammable gas from drift at bottom.
Sec. 4, T. 24, R. 4 E	775	140	Yellow till, 15 feet; soft blue till, 11 feet; hard blue till, 12 feet; sand and gravel, 6 feet; hard blue till, 40 feet; soft blue till, 56 feet.
Sec. 9, T. 24, R. 4 E	775	95	Yellow till, 15 feet; soft blue till, 65 feet; hard sandy blue till, 15 feet.
Sec. 28, T. 24, R. 4 E	850	198	Mainly till, 136 feet; sand and gravel with gas, 62 feet; shale at bottom.
Sec. 36, T. 24, R. 4 E	850	180	Mainly sand; probably rock at bottom.
Sec. 6, T. 24, R. 4 E	800	230	Yellow till, 18 feet; blue till, 60 feet; white sand, 80 feet; blue sand, 50 feet; gravel, 7 feet; blue clay to bottom, 13 feet.
Sec. 29, T. 24, R. 1 W	725	256	Loess and yellow till, 12 feet; blue clay with few pebbles, 244 feet; gas at 111 feet.
Sec. 29, T. 24, R. 1 W	725	192	Loess and yellow till, 12 feet; blue clay, few pebbles, 95 feet; hard blue till, 83 feet; no rock.
Sec. 34, T. 24, R. 1 W	725	200	Loess and yellow till, 18 feet; soft blue till, 182 feet; rock, perhaps a bowlder, at bottom.
Sec. 2, T. 23, R. 1 W	725	217	Mainly blue till; gravel at bottom.
Sec. 3, T. 23, R. 1 W	725	246	Blue till entered at 40 feet; black muck with wood and leaves at about 200 feet.
Mrs. Cowden, at Gillem	820	116	Mainly blue till; gravel at bottom.

Wells of McLean County—Continued.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
E. McGraw, 1 mile east of Gillem.	825	127	Mainly blue till; gravel at bottom.
Southwest part T. 23, R. 4 E	850	187	No rock struck.
Sec. 7, T. 22, R. 4 E	800	176	Yellow silt and till, 15 feet; soft blue till, 24 feet; black muck with wood, 4 feet; greenish clay, 10 feet; gray clay and sand, 8 feet; blue-gray till, 113 feet.
J. Painter, 5 miles north of Le Roy.	825	190	No rock struck.
H. Vert, 4 miles north of Le Roy	875	221	No rock struck.
Leroy, coal boring	778	200	Mainly till, 56 feet; sand, 145 feet; no rock.
Sec. 3, T. 22, R. 4 E	850	100	Gas from drift at about 100 feet.
4 miles northeast of Ellsworth.	850	100	Gas from drift at about 100 feet.

VERMILION COUNTY.

GENERAL STATEMENT.

Vermilion County is situated on the east border of the State, about midway of the east line, and has an area of 926 square miles, with Danville as the county seat. It is drained mainly by Wabash-Vermilion River, whose North Fork leads through the northeastern part of the county, the Middle Fork through the northwestern, and Salt Fork through the western. The south border of the county is drained eastward through Little Vermilion River and the extreme northwest border is drained northward to the Iroquois River.

The north-central portion of the county is occupied by the Bloomington morainic system, which is here differentiated into two belts, each of which in places presents a double ridge. The south border of the county is traversed by the Champaign morainic system, whose main ridge lies south of Little Vermilion River, but which has a minor ridge leading eastward across the county a few miles farther north than this stream.

In the southern half of the county the drift is generally of shallow depth, rock being entered frequently at 30 or 40 feet, or even less. In the northern half of the county the thickness is much greater. The few borings of which records were obtained indicate that it may average not less

than 200 feet. The elevation of the northern portion is greater than the southern, but not so much as the difference in the thickness of drift, being perhaps 50 or 75 feet greater.

In the northern half, where the drift is thick, the structure is similar to that of Iroquois County, which borders it on the north; there being a soft blue till about 100 feet in thickness along the moraines, and of somewhat less depth on the narrow plains between them. Beneath this till there is frequently a black muck or soil, under which a harder till sheet sets in. In places the lower portion of the drift is sand or gravel instead of hard till. In the southern part of the county, where the drift is comparatively thin, it consists of soft till similar to the surface portion in the district to the north. The older sheets of drift are apparently present only in thin deposits.

Many flowing wells have been obtained in the valley of Middle Fork, near Potomac. J. M. Crayton, in a letter addressed to the Director, February 3, 1897, reported that within a square mile in the vicinity of Potomac there are over 200 flowing wells, varying in depth from 65 to 140 feet, each throwing a continuous and never-failing 2-inch stream of palatable water. The water is obtained from beds of sand below blue till, and there are three or more water-bearing beds, separated by thin beds of till or clay. The wells situated on low tracts between morainic ridges in this county have generally a strong hydrostatic pressure, with head but a few feet below the surface. The absorbing area is, in all probability, on the neighboring moraine. The sheets of drift are usually so arranged that water absorbed by a moraine may readily pass northward beneath the neighboring till plain. In the southern portion of the county there is also some rise in the wells, especially if made on slopes north of the moraines. The wells there are, however, shallower than in the northern portion of the county, and conditions are, on the whole, less favorable for obtaining flowing wells.

INDIVIDUAL WELLS

The public water supply of Hoopeston is from a well 350 feet in depth, which enters rock only 50 feet. The upper 30 feet of the drift is clay and sand, the remainder principally gravel. The well is only 8 inches in diameter, yet in 1895 it had an estimated capacity of 2,000,000 gallons a day. The head is about 20 feet below the surface. The water is moderately hard, and has a small amount of sulphate of sodium and a still smaller amount of sulphate of magnesium, but is very palatable. The

Manual of American Waterworks (1897) reports two 8-inch driven wells at the waterworks. Many wells are obtained in the vicinity of Hoopeston at depths of 80 to 100 feet, in sand or gravel below blue till.

At East Lynn wells are usually obtained at depths of 40 to 60 feet, in gravel or sand below a sheet of till.

At Rossville a coal boring about 500 feet in depth entered hard rock at 190 feet. There is 125 feet of blue till forming the upper part of the drift, beneath which is 60 feet of cemented material, called by the driller a soft sandstone, under which there is a water-bearing gravel resting on the rock. A similar cemented material was penetrated in a boring about 5 miles north of Rossville. It sets in under the blue till at a depth of 150 feet, and is underlaid by a yellow, pebbly clay, extending to the rock at 235 feet. The Manual of American Waterworks reports that the public supply at Rossville is from a deep well.

The public water supply for the city of Danville is pumped from the North Fork of Vermilion River. Wells in the city usually enter rock at a depth of about 15 feet and obtain water at a depth of 60 to 75 feet, which is near the level of the Vermilion River. A deep well sunk at Danville Junction to a depth of 2,008 feet has the following section, reported by J. G. English, of Danville:

Section of a well at Danville Junction, Illinois.

	Feet.
Yellow till and gravel	20
Blue till	15
Hardpan	30
Blue till	15
Sandy loam	10
Clay, sand, and gravel	50
Muck bed with wood	8
Tough blue clay	25
Sand and gravel	2
Coal Measures and Devonian strata	950
Hard gray limestone (probably Upper Silurian)	51
Soft gray limestone with H_2S gas	10
Limestone, both dark and light colored	160
Soft white limestone with H_2S gas	12
Limestone, both dark and light colored	342
White sandstone (St. Peter?), and brackish water	35
Clay shale	110
Gray limestone	125
Blue limestone	65
Blue shale	57
Red rock	15
Total depth	2,008

A well near the waterworks in the Vermilion Valley penetrated to supposed Upper Silurian limestone, which it enters at a depth of 1,075 feet. The thickness of drift at the Danville Junction well much exceeds that of other wells in the neighborhood, and indicates that a preglacial valley was entered by the boring.

At Fithian, in the western part of the county, wells are usually obtained from sand or gravel associated with the till at depths of 50 feet or less, but one well was found to have a depth of 90 feet, of which the lower 15 feet is in rock.

At Fairmount rock is entered at slight depth, and wells usually are obtained at less than 50 feet.

At Indianola wells are obtained from sand or gravel below till at a depth of about 30 feet, a strong supply of water being found at this depth.

At the village of Ridge Farm the wells are usually obtained at a depth of 20 feet or less, in sand associated with till.

The flowing wells near Potomac, in the north part of the county, referred to above, usually penetrate the following series of drift beds, the section being furnished by George Platt, a well driller who has sunk several of the wells:

Generalized section of flowing wells near Potomac, Illinois.

	Feet.
Yellow pebbly clay (Wisconsin)	10–12
Blue clay, soft like putty, and containing few pebbles (Wisconsin)	60–70
Hard, stony clay, or ferruginous crust	1–3
Sand and gravel, with artesian water	6–10
Hard, partially cemented, sandy clay	25–30
Sand and gravel, with artesian water	5
Hard, partially cemented, sandy clay	15–20
Sand and gravel, with artesian water	several feet

Very few records of deep wells were obtained in this county outside the villages just discussed. The record of a farm well, made in sec. 31, T. 23, R. 13 W., shows 240 feet of drift, mainly till of a blue color, at the bottom of which water was obtained in sand and gravel. A well in sec. 36, in the same township, penetrated drift a depth of 160 feet without reaching rock, and a well near Alvin a depth of 173 feet.

CHAMPAIGN COUNTY.

GENERAL STATEMENT.

Champaign County is situated west of Vermilion, and has an area of 1,000 square miles, with Urbana as the county seat. The eastern and northeastern portions are tributary to the Vermilion River. The southern portion contains the headwaters of the Embarras and Kaskaskia rivers, and the northwestern portion is crossed by the Sangamon River. Much of the surface is so level that artificial ditching has been necessary to give good drainage. There are, however, two morainic systems crossing the county. The outer belt of the Bloomington system crosses the northeast corner, while the Champaign morainic system traverses the county in a southeast course, a little to the south of the center. The latter system consists of three distinct ridges in the southeast part of the county, which become united into a single ridge near Champaign, and continue united to southeastern McLean County, beyond which the morainic system is not traceable. The belt belonging to the Bloomington system has an average relief of about 50 feet above the plain bordering it on the southwest. The Champaign morainic system has even less average relief above the bordering plains.

In the portion of the county southeast from Urbana the drift has an average thickness of scarcely 100 feet, but throughout the remainder of the county its thickness is much greater. Records of 22 borings which did not reach rock show an average of 171 feet, and it is probable that the average for the county is not less than 200 feet. The drift to a depth of about 100 feet is, in the main, a soft blue till of Wisconsin age. On the moraines the depth is correspondingly greater. Prof. C. W. Rolfe, of the University of Illinois, reports that throughout much of the county wells are found to pass through a buried soil immediately below the blue till, and then to enter a harder till. The writer found exposures, of which description has already been given (p. 216), of a peaty muck or soil along the bluffs of the Sangamon River in the western part of the county.

Many wells have been sunk through the blue till into beds of sand or gravel associated with the underlying harder till, as shown in the discussion below. Throughout much of the county the wells have strong hydrostatic pressure, though they seldom overflow.

INDIVIDUAL WELLS.

In the vicinity of Ludlow, in the north part of the county, at an altitude about 800 feet above tide, several wells have been sunk to a depth of 150 feet without reaching rock. They are largely through till.

A well at F. Delaney's near Dickerson, in the northwest part of the county, at an altitude about 750 feet above tide, reached a depth of 280 feet without encountering rock.

In the vicinity of Rantoul the wells range from 80 to 200 feet in drift. The public water supply for this village is obtained from a well 135 feet in depth, mainly through blue till. A prospect boring for coal at this village, reported in the Geology of Illinois, is said to have reached rock at a depth of 80 feet. The report, however, is based upon rather imperfectly supported data, the results of the boring having been kept secret for about twelve years before they were communicated to the Survey.[1]

Near Gifford, in the northeast part of the county, on the crest of the outer ridge of the Bloomington morainic system, a well is reported to have reached a depth of 260 feet and little or no rock was penetrated. No more definite record of the well was obtainable.

In the vicinity of Mayview several wells have been obtained in sand and gravel below till at depths of 80 to 100 feet. A well at the residence of T. Hissong in Mayview reached a depth of 118 feet.

The cities of Champaign and Urbana have a common public water supply obtained from seven wells sunk to depths of 157 to 162 feet in the glacial drift. The combined daily capacity of the wells is nearly a million gallons. The wells range in diameter from 5 to 8 inches. Two coal borings at Urbana show a difference of 165 feet in the distance to rock, one entering rock at 100 feet, the other at 265 feet. The drift section of the deeper one, furnished by Prof C. W. Rolfe, appears on page 235.

At Champaign a deep boring prospecting for coal and gas, as indicated in the section on page 234, has penetrated a deposit of drift even thicker than in the deepest boring at Urbana, it being 300 feet, but the altitude is about 30 feet higher than at the Urbana boring, thus giving the rock surface nearly the same altitude at both places.

At Sidney the dug wells are about 30 feet and bored wells 30 to 70

[1] Geology of Illinois, Vol. IV, p. 274.

feet in depth, water being obtained in beds of sand and gravel associated with till. A prospect boring for coal at this village entered rock at 95 feet. The section of the drift penetrated appears on page 236.

In the vicinity of Homer wells are usually obtained at about 30 feet, and rock is entered at 90 feet. South from Homer, near the southeast corner of the county, wells are usually obtained at 20 to 40 feet, but occasionally reach a depth of 100 feet without entering rock.

At the village of Philo, which is situated on the crest of one of the ridges of the Champaign system, a well reached a depth of 171 feet without entering rock (see p. 235).

Several wells in the vicinity of Philo reach a depth of 100 feet without entering rock.

At Mahomet several wells obtain water at 45 to 50 feet. A well in this village at D. McArthur's has the following section:

Section of McArthur well at Mahomet, Illinois.

	Feet.
Gravel	7
Pebbleless clay	3
Brown and gray till	32
Black muck	2
Hard till	58
Total depth	100

A well at Jonas Lester's, a half mile south of Mahomet, passes through a black soil below till at about 36 feet. The section of an exposure in the Sangamon bluff south from Mr. Lester's appears on page 216.

A well at George Frankenburgher's, 2 miles east of Mahomet, at an altitude 60 feet higher than the village, reached a depth of 200 feet without entering rock. About 4 miles southwest from Mahomet, on ground no higher than the village, records of three wells were obtained which penetrate over 200 feet of drift, mainly blue till, without entering rock (see pp. 219–220).

PIATT COUNTY.

GENERAL STATEMENT.

Piatt County is situated in the east-central part of the State, immediately west of Champaign County, and has an area of 440 square miles, with Monticello as the county seat. The Sangamon River leads southwestward through the central portion of the county, and is the only stream of

importance within its limits. Much of the county has a very level surface which requires artificial drainage.

The few borings of which records were obtained indicate that the county is covered with a very thick sheet of drift, averaging probably more than 200 feet. The greater part of the drift appears to be blue till. Shallow wells of moderate strength are often obtained at depths of 25 to 40 feet, but tubular wells are usually sunk to depths of 100 feet or more and obtain stronger supplies than at shallow depths.

INDIVIDUAL WELLS.

At Monticello the public water supply, as noted on page 220, is from two wells 212 and 316 feet in depth, neither of which enters rock.

At Bement the public water supply is obtained from two wells, one 138 feet, in gravel below till, the other 225 feet, in rock the lower 3 feet. The shallower one obtains the larger supply of water. The Wabash Railway has a strong well at this village 152 feet in depth, from gravel below till. A well at the mill, 141 feet in depth, is also in gravel below till. Joseph Rodman sunk a well to a depth of 384 feet, which entered rock at 205 feet. A well at the Bement cemetery, 2 miles north of the village, at an altitude about 45 feet higher, reached a depth of 221 feet without entering rock, and a well one-half mile east of the cemetery, 222 feet in depth, did not reach rock.

At Cerro Gordo several wells have been sunk to a depth of about 150 feet without reaching rock. They are mainly through blue till, and in some cases are rather weak.

A well near Mansfield, on the farm of Mrs. R. Carson, as noted on page 234, reached a depth of 200 feet without entering rock, mainly through sand.

DEWITT COUNTY.

GENERAL STATEMENT.

Dewitt County is situated in the central part of the State, west of the northern portion of Piatt County, and south of McLean County. It has an area of 405 square miles, and Clinton is the county seat. Salt Creek, a tributary of the Sangamon River, leads westward through the central portion of the county, and is the main stream within its limits. The western

part of the county is traversed by the outer moraine of the Wisconsin drift sheet, which here has a relief of nearly 100 feet above the plain to the west, but rises only a few feet above the plain to the east.

The drift of this county, like that of the neighboring counties, Piatt and McLean, is very heavy, averaging probably more than 200 feet. The upper 100 feet is mainly a blue till, except on the plain outside the Wisconsin drift, where much sand and gravel occurs. The few deep wells sunk on the newer drift indicate that the sandy drift continues eastward under the Wisconsin drift sheet. In several places buried soils, or muck beds, have been found about the level of the base of the Wisconsin drift. There are also numerous instances of inflammable gas from beds of sand and gravel in the drift.

INDIVIDUAL WELLS.

But few records of wells have been obtained in this county, and these are of considerable depth. Wells are often obtained at moderate depths in sand or gravel associated with the blue till.

At Farmer City the public water supply is from a well 176 feet in depth, which terminates in sand. The head is now a few feet below the surface, but when first made the well overflowed. A prospect boring for coal at this town entered rock at a depth of 189 feet. The upper half of the drift is mainly till, the lower half largely sand and gravel. (See section on page 216.)

A well one mile north of Parnell, 200 feet in depth, did not enter the rock.

At Clinton strong wells are obtained from sand and gravel below till at depths of 80 to 110 feet. The public water supply is obtained from several wells about 110 feet in depth. The following detailed record of the drift penetrated at Clinton, in a prospect boring for coal, made with a diamond drill, is taken from the Geology of Illinois:[1]

Drift beds in a prospect boring for coal at Clinton, Illinois.

	Feet.
Surface soil	5
Quicksand	15
Sand with gravel and bowlders	17
Sand and clay mixed	53
Hardpan	12
Gravel	1
Hardpan	4

[1] Vol. VIII, p. 34.

	Feet.
Clay and sand	4
Gravel and clay	7
Hardpan	3
Clay and sand	7
Clay and gravel	14
Clay	4
Hardpan	6
Clay and gravel	8
Quicksand	5
Sand and gravel	2
Coarse gravel	2
Clay	6
Gravelly hardpan	25
Quicksand	6
Sand and clay	7
Gravel	9
Sand	11
Gravel	9
Sand	9
Quicksand and gravel	101
Total depth of drift	352

This boring continued to a depth of 942 feet without reaching the bottom of the Coal Measures. A boring about one-half mile farther north was carried to a depth of 539 feet and penetrated only 270 feet of drift, or 70 feet less than that whose section is just given.

The section of a gas well at James Barnett's, 8 miles west of Clinton, also reported in the Geology of Illinois, appears on page 205. It is stated that dry sand and pebbles were thrown out upon the surface by the pressure of the gas which was struck at the bottom of this well.

In the vicinity of Hallsville several gas wells have been obtained from beds of gravel between sheets of till at a depth of 117 to 127 feet. The gas is used in some cases to supply light and fuel for dwellings.

At Kenney, on the low plain outside the Wisconsin drift sheet, at an altitude only 650 feet above tide, a boring was sunk to a depth of 291 feet, mainly through sand and gravel, without reaching the rock.

At Waynesville, in the northwest corner of the county, on the outer slope of the moraine which marks the limit of the Wisconsin drift, the public water supply is obtained from wells 150 feet in depth.[1]

In the vicinity of Wapella wells seldom obtain a good supply of water at less than 65 feet, and several are 80 to 100 feet in depth. They penetrate only 8 to 12 feet of surface silt and yellow till before entering blue till.

[1] See Manual of American Waterworks, 1897

The blue till extends to about 80 feet. At this depth a black mucky soil containing wood is found, which is underlain by a green clay, apparently a swamp subsoil. The muck and associated green clay are often several feet in thickness. They rest upon a harder till than that which overlies them. Occasionally gas is struck in sand near the level of the buried muck, but not in sufficient amount to be utilized for fuel.

LOGAN COUNTY.

GENERAL STATEMENT.

Logan County is situated in the central part of the State, with Lincoln as the county seat, and has an area of 620 square miles. It is drained by Salt Creek and its tributaries, the principal tributaries being Sugar Creek, Kickapoo Creek, and Lake Fork. With the exception of the northeast corner, it lies outside the limits of the Wisconsin drift and its drainage systems are much more mature than those on the Wisconsin drift to the east, though the elevation is about 100 feet lower than on neighboring portions of the Wisconsin drift. In addition to a better drainage system, there is a coating of loess, which absorbs the excess of rainfall much more rapidly than the till which forms the surface of much of the Wisconsin drift, and returns the moisture to the crops in seasons of drought to a larger extent than the till sheet.

The thickness of drift is known only at a few points in the southwest part, where it is 60 to 100 feet. The thickness in the northern and eastern parts of the county apparently averages at least 150 feet, several wells having reached that depth without entering rock. The drift in the southern and eastern portions of the county is largely till, but in the northwestern part it apparently consists in the main of sand and gravel, thus resembling the drift of Mason County, which borders it on the west.

Wells are usually obtained at depths of 20 or 30 feet, which have sufficient strength to supply stock as well as households. In a few cases, however, wells have been sunk to depths of 100 or even 200 feet.

INDIVIDUAL WELLS.

The village of Atlanta, which is situated on the outer moraine of the Wisconsin drift, obtains its supply for the waterworks from a well 151 feet in depth, a section of which appears on p. 206. In the vicinity of Atlanta

several wells reach a depth of 125 feet, and occasionally a well is sunk to a depth of fully 200 feet without entering rock. The well drillers report that the upper 100 feet is a softer clay than the lower 100 feet. A buried soil is not uncommon at the base of the soft clay. It is probable that the soil immediately underlies the Wisconsin drift, though it may in some instances be at a lower horizon.

At Lawndale, situated on the plain immediately outside the Wisconsin drift sheet, at an elevation about 115 feet lower than Atlanta, several wells have been sunk to depths of 65 to 80 feet, mainly through a hard till. Water is found beneath a cemented gravel in a loose gravel or sand. East from this village wells are in several instances 50 or 55 feet in depth, and enter gravel below till.

At Hartsburg the public well is obtained in sand below till at a depth of 95 feet. Another well in the village is thought to have struck rock at about 100 feet.

In the vicinity of Emden, on the plain outside the Wisconsin drift, in the north part of the county, tubular wells are 85 to 200 feet in depth without entering rock. They usually penetrate alternations of till with sand or gravel beds. Well drillers report that west from Emden the wells frequently penetrate a dry gravel to depths of 90 to 115 feet. Southwest from Emden a sand and blue silt frequently constitutes almost the entire section to a depth of at least 100 feet. A well at Mr. Hubbard's, in sec. 31, T. 21, R. 4 W., 196 feet in depth, has the following section:

Section of the Hubbard well in Sec. 31, T. 21, R. 4, W.

	Feet.
Yellow clay, mainly loess	16
Blue clay, nearly pebbleless, called "blue mud"	150
Hard blue clay (till?)	30
Gravel at bottom.	
Total depth	199

At Lincoln a strong supply of water is obtained from sand at about 65 feet after penetrating beds of clay, sand, and gravel. The public water supply is mainly obtained by pumping from neighboring creeks, though wells have been used.

In the vicinity of Broadwell the drift is mainly a blue till and is 60 or 70 feet in depth. Wells are frequently obtained above the blue clay at depths of 15 or 20 feet.

At Elkhart the drift is about 60 feet in depth, as follows:

Generalized section of drift at Elkhart, Illinois.

	Feet.
Loess and slightly pebbly clay	12
Black soil containing wood	3–6
Yellow till	5–10
Blue till	30–35

Records of several wells were obtained west from Elkhart which show a section similar to the above and enter rock at about 60 feet.

At Mount Pulaski the public water supply is from a well about 80 feet in depth, which is mainly through a sandy drift. The village stands on a knoll, about 40 feet above the bordering plain. On the plain near Mount Pulaski a black mucky soil is penetrated below yellow clay at a depth of 16 or 18 feet, and wells are obtained at about 30 feet. A prospect boring for coal on the plain near this village penetrated 92 feet of drift.

MENARD COUNTY.

GENERAL STATEMENT.

Menard County is situated in the central part of the State, immediately west of Logan County and south of Mason County. It has an area of only 320 square miles, and Petersburg is the county seat. The county is traversed nearly centrally in a south-to-north direction by Sangamon River, and this stream also forms a portion of the north boundary of the county. The remainder of the north boundary is formed by Salt Creek, the principal tributary of Sangamon River. The county is well drained by these streams and their tributaries, and has also a coating of loess which absorbs the rainfall rapidly and returns it to the crops in seasons of drought.

The drift has about the same constitution as in southwestern Logan County, being largely a hard blue till. Its depth is seldom less than 60 feet, and probably averages at least 100 feet. Wells are usually obtained at about 35 feet, though a few have been sunk to greater depths. Borings for coal have tested the thickness of the drift at several points.

INDIVIDUAL WELLS.

The public water supply at Petersburg is obtained from four 8-inch wells sunk to depths of 35 to 60 feet in the glacial drift. A coal shaft in the Sangamon Valley, 2 miles north of this city and at about 65 feet lower elevation, entered rock at 46 feet.

In the vicinity of Greenview the drift is less than 100 feet in thickness. The loess has a depth of 12 to 16 feet, and is separated from the underlying till by a definite soil horizon.

The record of a boring at Sweetwater, published in the Geology of Illinois, is as follows:

Section of a boring at Sweetwater, Illinois.

	Feet.
Brown clay	40
Sand	11
Blue clay	59
Total drift	110

Black soil at bottom of drift.

Another deep boring reported in the Geology of Illinois, is in a valley in sec. 2, T. 17, R. 6 W., which reached a depth of 86 feet without entering rock. Wood was found at 65 feet.

Outcrops of rock occur in the west part of T. 18, R. 5 W., along ravines at a level only 35 feet below the neighboring uplands, and wells east from there near the county line enter rock at about 70 feet.

CASS COUNTY.

GENERAL STATEMENT.

Cass County is situated on the east side of the Illinois River, immediately south of the mouth of the Sangamon River, with Virginia as the county seat, and has an area of 360 square miles. It is drained by small streams tributary to the Sangamon and Illinois, and its drainage is much like that of Menard County, rainfall being disposed of by the loess as well as by a well-developed drainage system. There are extensive bottom lands along the Sangamon and Illinois rivers, occupying about one-third the area of the county. These bottoms have a sandy deposit, though usually their soil is productive.

Wells at Beardstown indicate that the Illinois Valley has a filling of at least 100 feet, mainly sand and gravel. On the uplands the drift thickness is known to the writer at only two points—Ashland and Virginia—being 85 feet at the former and 187 at the latter village.

Wells are usually obtained at 25 to 50 feet, both on the bottom lands and on the upland. The shallower ones obtain their supply above the blue till, but the deeper ones on the uplands enter that deposit a few feet.

INDIVIDUAL WELLS.

The public water supply at Beardstown is obtained from driven wells about 80 feet in depth. The wells show a gradation downward from sand through fine gravel to coarse gravel. Several artesian wells have been sunk at this city which penetrate about 100 feet of drift and reach depths of 1,050 to 1,100 feet. A flow of water is obtained from strata supposed to be Devonian at about 350 feet, and another flow with small amounts of gas and oil at 500 to 600 feet, and a third flow from near the bottom. The wells are estimated to have a capacity of about 175 gallons a minute.

At Virginia wells are usually obtained at 25 to 50 feet from sand and gravel below clay. The beds of sand and gravel are not certain to occur, and only those wells which are so fortunate as to strike them obtain an abundant supply of water. Dr. J. F. Snyder, of Virginia, reports that during the drought of 1894 and 1895 about 70 per cent of the wells in the vicinity of Virginia became dry. The coal shaft at this village, 220 feet in depth, penetrated 187 feet of drift. It was mainly through till, but a black soil was passed through at 67 to 70 feet. This coal shaft is stated by Dr. Snyder to have afforded, during the drought referred to above, about 375 barrels of water a day. A boring at Virginia 730 feet in depth obtained a water strongly impregnated with sulphur and iron, which is considered unfit for general use. A remarkable thickness of peat was penetrated by a well at Mr. Oldridge's, in this village, of which an account appears on a previous page (p. 127). The section at Ashland has also been discussed (p. 127).

SCHUYLER COUNTY.

GENERAL STATEMENT.

Schuyler County is situated on the west border of the Illinois River, northwest from Cass County, and has an area of 430 square miles, with Rushville as the county seat. Crooked Creek crosses its northwest corner and forms a portion of the western border. No other prominent stream occurs in the county, but it has a somewhat mature drainage system, and portions of the county are very much broken by ravines. There is a loess coating, as in the counties east of the Illinois River, which adds to the ready disposition of the rainfall. The Illinois bottoms lay mainly east of the

river opposite this county, but extend about 2 miles into the county near the south border, above the mouth of Crooked Creek.

The drift deposits appear to be much thinner than in the counties east of the Illinois, just discussed, rock being entered in many places at a depth of about 30 feet. The wells are usually obtained above the rock at depths of 15 or 20 feet.

INDIVIDUAL WELLS.

At Rushville the present public supply is from impounded water fed by springs. From 1894 to 1896 a well 2,500 feet in depth supplied the waterworks. The quality of the water was found so unpleasant that its use was discontinued. The distance to rock varies 50 feet or more within the limits of this town. At the creamery rock was entered at only 20 feet, but at the northeast corner of the public square a well reached a depth of 70 feet without entering rock. A coal mine on the outskirts of the town enters rock at about 40 feet. The drift is mainly sand and gravel, while in the well at the public square it is mainly till.

East from Rushville, in the vicinity of Pleasant View, wells are reported to enter a blue shale at depths of 17 to 24 feet, but as some of them are also thought to enter gravel below this material it is probable that the material is till rather than shale. These wells enter limestone at about 60 feet, and this probably represents the thickness of the drift.

In the interior of the county, northwest from Rushville, wells are found to enter rock at depths of 30 to 50 feet, though occasionally a greater depth is reached without encountering rock.

BROWN COUNTY.

GENERAL STATEMENT.

Brown County is situated on the west border of the Illinois River, immediately south of Schuyler, and has an area of 300 square miles, with Mount Sterling as the county seat. Crooked Creek forms a portion of the northern border and receives the drainage of the northeast half of the county. McKee's Creek crosses the southern border of the county and drains its southwestern portion. In thickness and structure the drift in this county is similar to that of Schuyler. The surface also is generally much eroded and the drift is capped by a deposit of loess. The thickness of the

loess is usually but 10 or 15 feet. On the borders of the Illinois, however, it attains in one place a thickness of over 100 feet, a large part of the bluff being formed of that deposit. The Illinois bottoms occupy an average width of about two miles along the east border of the county, and the higher portions of the bottoms are sandy and gravelly, but the lower portions are covered with a deposit of muck.

Although the drift is comparatively thin throughout much of the county, wells are usually obtained without entering the rock. The rock consists largely of a sandy shale, which often affords water in fair amount.

INDIVIDUAL WELLS.

At Mount Sterling the wells are usually obtained from sandy clay at depths of 16 to 25 feet. The Manual of American Waterworks states that the public supply is from an open well.

In the vicinity of Mount Sterling shale is often struck at about 25 feet. The Illinoian drift embraces only about half this depth, there being 10 or 12 feet of loess at the surface.

In the vicinity of Versailles wells are often sunk to a depth of 50 feet, and they are largely through loess.

At Mound Station, in the northwest part of the county, a well at the lumber yard enters rock at 44 feet. The mounds or low hills immediately northwest of this station, which give it its name, are said to have a nucleus of rock which causes their relief of 50 feet or more above the plain.

ADAMS COUNTY.

GENERAL STATEMENT.

Adams County borders the Mississippi River in the western part of the State, with Quincy as the county seat, and has an area of 830 square miles. The northern third of the county is drained westward through Bear Creek, the southwestern part is drained westward through Mill Creek, and the southeastern part is drained eastward through McKee's Creek, a tributary of the Illinois River. In the western, central, and southern portions of the county there are several ridges of drift formed near the western border of the Illinoian drift sheet and trending in a general northwest-southeast direction. These ridges are each a mile or less in average width and rise 20 to 50 feet above the bordering plains. Their distribution is shown on the

glacial map, Pl. VI. Aside from these few ridges, the drift has a plane surface and the drift filling is sufficient to nearly conceal preglacial valleys. With the exception of a narrow strip along the Illinois-Mississippi divide, in the central and northeastern parts of the county, the surface is generally much eroded. In the vicinity of the Mississippi bluffs there is a thick deposit of loess, in places reaching 50 or 60 feet, but within 5 or 6 miles back from the brow of the bluffs the thickness decreases to 10 feet or less. The loess affords quick absorption for the rainfall and supplies moisture to the crops in seasons of drought.

The glacial drift is largely till. It is underlain in places by deposits of preglacial sand, first brought to notice by Worthen and later examined in more detail by Salisbury and the writer. The heaviest deposits noted are in the vicinity of Mendon, in the northwest part of the county, but deposits of considerable depth also occur along the Illinois-Mississippi divide in the southeast part of the county. In the former situation their elevation is 150 to 200 feet above the Mississippi River, and in the latter nearly 300 feet above that stream, or on about the highest rock surface known within the limits of the county. The thickness of the deposits and their relation to wells is set forth in the discussion below.

The wells of this county are usually obtained at moderate depths in the drift. In nearly every township, however, several deep wells have been sunk. Records of 59 such wells were collected which show an average depth of about 63 feet. The rock was struck in 36 wells at an average depth of 61 feet. In the remaining 23 wells the average depth is 65 feet. From these wells it appears probable that the average thickness for the county is not less than 65 feet. None of the well records were obtained in the Mississippi bottoms, which occupy about 100 square miles of the county and in which the drift is probably more than 100 feet in average depth, for the valley floor of the preglacial river was cut to a level fully 100 feet below the present stream.

INDIVIDUAL WELLS.

The public water supply for the city of Quincy is pumped from the Mississippi River, but there are numerous private wells in the city, ranging in depth from 90 to 200 feet. These wells are mainly through limestone. In parts of the city 30 feet or more of loess is penetrated before the limestone is entered.

At Mendon the public water supply is from a well 1,010 feet in depth, from which water is pumped to a tank. This well passed through about 20 feet of loess and glacial drift, beneath which a deposit of orange-colored sand, presumably preglacial, was found, which extends to the limestone at 70 feet from the surface. Another well, at the public square, on ground 20 feet higher than the deep well, also penetrated a large amount of sand and entered limestone at a depth of 94 feet. Samples of this sand examined with acid are apparently free from calcareous material, thus differing markedly from the glacial sands of this region, which are composed largely of limestone fragments. The sand is also stained a deeper yellow than that associated with glacial drift.

A well at W. W. Benton's, 1 mile west of Mendon, reached a depth of 400 feet, but the water supply is mainly from about 200 feet. The drift penetrated in this well is as follows, the determinations being made by the writer at the time the well was sunk:

Section of Benton well near Mendon, Illinois.

	Feet.
Loess	12
Gray gummy soil	2
Yellow sand	18
Gray gummy clay, apparently a soil	6
Gray sandy clay with few pebbles	35
Blue clay with a few pebbles	10
Total	85

On ravines southeast of Mendon the following strata are exposed:

Section in a ravine southeast of Mendon.

	Feet.
Loess	8
Black gummy soil-like clay	1–2
Sand	5–10
Gray sandy clay, resembling soil	1–2
Brownish clay or clayey sand with pebbles, of variable depth, and underlain by yellow sand, apparently preglacial	20–40

In the vicinity of Fowler, wells are usually obtained in the drift at depths of 20 to 40 feet, but a well at the mill was sunk to a depth of 262 feet and entered rock at 80 feet.

At Coatsburg, a well at the mill reached a depth of 95 feet without entering rock. The drift is mainly till to a depth of 65 feet, beneath which there is a blue clay with sandy partings which is thought from the description to be a water deposit. Waterworks recently constructed at this village

use a well for supply, but the depth is not ascertained. A coal shaft 1 mile east of Coatsburg, reported in the Geology of Illinois, passed through a clay similar to that at the mill in its lower portion, which was separated from the overlying till by a black soil, the following being the section, supplemented by notes taken by the writer from the residents and from exposures near the coal shaft; it should be compared with the section given on page 62.

Section in a boring for coal a mile east of Coatsburg, Illinois.

	Feet.
Soil and yellow clay	6
Gray or ashy clay, resembling a soil	4
Yellow till, becoming gray or blue near bottom	10–15
Blue-gray till	70–75
Black soil	2½
Stratified clay	6
Tough blue clay	20
Total drift	118

At the County Infirmary near Coatsburg, a well entered rock at a depth of 165 feet. The upper 65 feet appears to be largely till, below which is a blue silt with sand partings, perhaps a water deposit. A boring at Mr. Henry's, near the infirmary, penetrated a similar section and entered rock at 160 feet. Another well on the infirmary farm is only 58 feet in depth. After penetrating about 40 feet of till it entered sand and gravel, which furnished the water.

At Camp Point wells are usually obtained at 25 to 30 feet. A few have, however, been sunk to a depth of 45 or 50 feet, at which depth the first rock is struck.

At Clayton rock is usually entered at a depth of 30 or 40 feet. The depth of wells supplying the waterworks has not been ascertained; the system was but recently introduced.

At Liberty several deep wells have been sunk which show a range in thickness of drift from 47 feet to at least 90 feet. A well at Collins's mill, 90 feet in depth, has the following section:

Section of a well at Collins's mill in Liberty, Illinois.

	Feet.
Till, mainly of yellow color	50
Blue clay containing much wood, but with few pebbles	35
Sand with water	5
Total depth	90

A well in Liberty, at William Lytle's, after penetrating 52 feet of till, entered a sandy blue clay containing wood. Water was found in this clay.

A well at Mr. Grubb's, on ground 20 feet higher, entered Coal Measures shale at 47 feet. The drift is largely gravel. Mr. Grubb, who has had some experience as a well driller, reports that over an area of several square miles northwest from Liberty the till has a thickness of about 50 feet and is underlain by a dark-blue clay similar to that of wells at Liberty and probably similar to that at the infirmary noted above. In a well examined by the writer while in process of excavation, a section of which appears on page 61, it was found that the dark-blue clay is a calcareous silt free from pebbles.

In the vicinity of Burton wells are usually obtained at about 30 feet, near the base of the drift. Two wells southwest of the village reach a much greater depth and apparently strike into a preglacial valley. One at Mr. Dietreck's, on the east bluff of Mill Creek, has a depth of 200 feet and enters rock at 160 feet. A well at Mrs. Ihrig's, on the west bluff of Mill Creek, reached a depth of 155 feet without entering rock. It was mainly through yellow clay to a depth of 105 feet, beneath which the clay is of blue color. Sand was struck near the bottom.

In the vicinity of Newtown (Adams post-office) wells not infrequently reach a depth of 75 feet, there being a ridge of drift leading past the village in a northwest-southeast course, in which wells are sunk to a greater depth than on the bordering plains. The village well, 75 feet in depth, is reported to be mainly till with gravel at bottom. Another well on the ridge southeast of the village, at the residence of Mrs. Wittemeyer, the section of which is given on page 59, passed through a gray muck or soil below till at 40 to 45 feet, which is about the level of the base of the ridge. Beneath this soil was a sandy till grading into sand below, and water is obtained in this sand at 80 to 82 feet.

At the village of Payson, which is located on a ridge of drift, rock is entered at a depth of about 90 feet, and the drift is largely of sandy constitution. A well at Mr. Barnard's, 1 mile west of this village, after penetrating alternations of clay and gravel to a depth of 60 feet, passed into a reddish clay, apparently formed by the decomposition of limestone, which was 17 feet in thickness and extended to the rock.

At Plainville the village well penetrates about 20 feet of clay containing few pebbles, beneath which is ordinary till extending to the rock, which is entered at about 40 feet. The drift in that vicinity seldom exceeds 40

feet in depth, and wells are often sunk some distance into the underlying limestone.

At Beverly the village well is 73 feet in depth, and apparently enters a preglacial sand in the lower 20 feet. This interpretation is made, however, from the examination of a well in process of excavation about one-half mile east of the village, at the residence of J. Sykes, the section of which appears on page 60. Mr. Sykes's well penetrated an orange-colored quartz sand in its lower 15 feet, which is entirely free from calcareous material and is apparently much older than the glacial drift. It so happens that at this well there occurs at the base of the glacial drift a bed of gravel and sand which is highly calcareous, and is much fresher in appearance than the quartz sand just referred to, a feature which lends much support to the interpretation of the preglacial age of the orange-colored sand.

Along the Illinois-Mississippi divide northwest from Beverly wells occasionally reach a depth of 90 feet without entering solid rock. They are reported to pass through an orange-colored sand in the lower part, which is probably similar to that examined in the well at Mr. Sykes's. Probably further study in the region would result in the discovery of natural exposures, for the ravines leading eastward from this divide are frequently cut to sufficient depth to reach the level of the orange-colored sand.

PIKE COUNTY.

GENERAL STATEMENT.

Pike County is situated between the Mississippi and Illinois rivers, immediately south of Adams and Brown counties, and has an area of 795 square miles, with Pittsfield as its county seat. Fully three-fourths of the county is tributary to the Mississippi River. It is probable that a larger portion is now tributary to the Mississippi than in preglacial times. As noted on page 480, the headwater portion of Bay Creek leads southeastward, as if to join the Illinois, but a morainic ridge on its east border prevents its entering the Illinois, and it passes westward through a hilly region which probably once constituted the divide between the Mississippi and the Illinois, and thus becomes tributary to the Mississippi.

The interior portion of the county is traversed by a series of drift ridges, which are the continuation of those noted in Adams County, and which, like those of Adams County, have a northwest-southeast trend.

Two of the ridges extend but little south of Pittsfield, but a third ridge, which, as noted above, follows the east border of Bay Creek, continues southeastward to the Illinois bluff, which it strikes between Montezuma and Bedford. These ridges constitute the highest land within the county, and reach in places an elevation of nearly 900 feet, and throughout much of their course are about 800 feet above tide. The rivers bordering the county have an elevation of less than 450 feet above tide, or about 400 feet below the general level of these ridges. Much of the upland in the county stands nearly 300 feet above the bordering streams.

Aside from the drift ridges just mentioned, the drift of the county is a thin deposit, scarcely forming a continuous coating. But in the drift ridges a thickness of about 100 feet is in places attained, and the thickness is seldom less than 50 feet. The drift in these ridges consists largely of a clay in which pebbles are less thoroughly intermixed than in typical till. The dumps of some wells examined, which reached the depth of 60 feet, show scarcely a handful of pebbles on their surface, while neighboring wells or natural exposures may contain a large amount of stony material. This imperfect intermingling of the stony and clayey material is probably due to the derivation of much of the drift from the immediate vicinity and the consequent short distance that it was transported. The loess forms a heavy deposit on the borders of the Illinois and Mississippi rivers, its usual thickness being 25 or 30 feet, but in the interior of the county its thickness decreases to scarcely 10 feet. On the higher portions of the drift ridges it is in places only 4 or 5 feet in depth.

Along the drift ridges wells are often obtained without entering the rock, but elsewhere on the uplands strong wells are seldom obtained in the drift. In the valleys of the Mississippi and Illinois wells are usually obtained in sand and gravel at about the level of these streams.

INDIVIDUAL WELLS.

In the vicinity of Barry, in the northwest part of the county, the wells are usually obtained in rock at a depth of 60 to 85 feet. The loess and drift is 16 to 35 feet in depth. The public water supply is from a well 2,510 feet in depth, which has a head 135 feet below the surface, except when filled with surface water after an intermission from pumping. The water, unless diluted with surface water, is too salt for domestic use and the majority of the citizens depend upon private wells.

At the village of Baylis, situated on the crest of the highest drift ridge in the county, a village well was sunk to a depth of 90 feet without entering rock. The upper 30 feet is of a clayey constitution, the remainder a fine sand. Wells are obtained in this village at the top of this sand. In ravines 1 to 2 miles southeast of Baylis there are exposures of drift about 50 feet in depth showing a brown surface clay with few pebbles, extending to a depth of 30 or 40 feet, beneath which there is a pebbly brown clay, streaked with gray, exposed to a depth of 10 or 20 feet. On the west slope of the drift ridge, west and southwest from Baylis, the pebbly clay near the base of the ridge is more gravelly than on the eastern slope, perhaps because of the removal of the clayey material as an outwash from the ice sheet. The section of a well at the residence of A. Hill, 2 miles north of Baylis, appears on page 63.

Along the county line northwest from Baylis the following section of drift deposits was found:

Section at roadside on county line northwest of Baylis, Illinois.

	Feet.
Loess or yellow silt	5
Ashy clay, probably soil	1–3
Yellowish-gray clay with few pebbles	40–50
Sand, gray or yellow, in thin beds	1–2
Ash-colored clayey sand, resembling soil	2–5
Cobble and gravel, with Canadian rocks	5–15
Total drift	60–85

At New Salem a well near the railway station obtains water in a gravelly clay at a depth of 30 feet, but in the main part of the village wells usually enter rock at about 20 feet and obtain water at depths of 40 to 50 feet.

In the vicinity of Griggsville the loess has a thickness of about 15 feet. Beneath it is a brown clay in which there are but few pebbles and which apparently extends to the rock. The village of Griggsville stands upon a slight elevation in which rock is nearly at the surface, but on the bordering plain rock is entered at greater depth, 25 to 35 feet.

In the vicinity of Detroit and Milton rock is occasionally entered at 30 feet, but wells along the drift ridge west and south from these villages are sunk to depths of 50 or 75 feet without entering the rock. A well at Marion Petty's, south of Milton, is reported to have passed through a black earth or soil containing wood at the base of the glacial drift, 30 to 35 feet from the surface.

At Time the village well has a depth of 70 feet. For a distance of 50 feet it is through a clay of brown color carrying few pebbles. The remainder is through a blue clay of the consistency of putty. Ravines in that vicinity show about 20 feet of loess, beneath which is a slightly pebbly brown clay. A well at J. E. Dinsmore's, 2 miles south of Time, reached a depth of 60 feet, mainly through pebbly clay, and did not strike rock. Mr. Dinsmore made another well in a ravine at an elevation about 40 feet below the one at his residence which passed through a black muck below brown clay at a depth of 40 to 45 feet and entered a red clay similar to the residuary clay formed from limestone in that vicinity It had not struck solid rock at a depth of 50 feet.

At Pittsfield the public water supply is from a well 2,200 feet in depth, which is used for fire protection and street sprinkling only. Private wells are obtained at moderate depth in the rock, seldom more than 50 feet. On the drift ridges west from Pittsfield wells reach depths of 30 to 50 feet without entering rock, obtaining their water from sandy drift associated with the clay.

At Nebo, in the valley of Bay Creek, wells are obtained at only 15 or 20 feet in sandy beds at about the level of the creek. On the bordering uplands wells are sunk into rock to depths of 50 or even 100 feet.

SCOTT COUNTY.

GENERAL STATEMENT.

Scott County has its west border on the Illinois River, opposite Pike County. Its area is but 250 square miles, and Winchester is the county seat. It is drained westward by tributaries of the Illinois, of which the principal ones are Mauvaise Terre and Big Sandy creeks. The Illinois bottoms occupy a strip about 3 miles in average width along the west border of the county. The uplands have a coating of loess, which is 25 to 50 feet in thickness on the border of the Illinois, but decreases eastward to scarcely more than 10 feet at the east line of the county. The drainage lines, together with the loess, dispose of the rainfall rapidly. In the Illinois River bottoms the sand is in places so light as to be barren in seasons of drought.

The drift in portions of the county is very thick, there being along the Illinois bluffs wide stretches in which no rock is exposed, though the bluffs

are over 100 feet in height. But in portions of the county the drift is only 20 or 30 feet in depth. The drift filling is sufficient to greatly conceal the courses of preglacial tributaries of the Illinois. Till forms the principal part of the drift, though in some parts of the county wells pass through a large amount of gravel and sand. The wells are usually 20 to 40 feet in depth and obtain water from the drift, very seldom entering the rock.

INDIVIDUAL WELLS.

In the vicinity of Winchester wells are usually obtained at a depth of 20 or 30 feet, but a well at the grist mill was sunk to a depth of 412 feet. It has a head 60 feet below the surface, or 470 feet above tide.

In the vicinity of Manchester wells are obtained at a depth of 20 or 30 feet. A coal shaft enters rock at about 60 feet.

In the vicinity of Alsey wells are obtained at about 40 feet. They penetrate 8 or 10 feet of loess, and then pass through till to the water-bearing bed at bottom.

Near Glasgow, on the Illinois River bluff, wells usually pass through about 25 feet of loess, 20 feet of yellow till, and 30 feet or more of blue till before entering rock. In some cases they are obtained above the rock.

MORGAN COUNTY.

GENERAL STATEMENT.

Morgan County is situated north and east of Scott County and touches the Illinois River for a few miles on its northwest border. It has an area of 580 square miles, and Jacksonville is the county seat. It is drained westward to the Illinois River through several creeks, of which Indian and Mauvaise Terre creeks are the largest. Like Scott County, this county has a heavy coating of loess on the border of the Illinois River, but only a thin deposit a few miles back from the Illinois The loess and drainage lines, as in Scott County, give excellent drainage.

The drift is thin in the southeast portion of the county, rock being at depths of but 20 or 30 feet in many of the wells, but in the remainder of the county the thickness generally exceeds 50 feet and in places reaches at least 150 feet. It consists largely of till, but gravel and sand beds are sufficiently abundant to supply water for most of the wells. The wells are seldom sunk to depths of more than 40 or 50 feet.

INDIVIDUAL WELLS.

In the extreme northwest part of the county, on the Illinois bottoms, wells are obtained in sand at 30 to 50 feet, or at about the level of the Illinois River. On the bluffs they are sunk through 20 feet or more of loess before entering glacial drift. Rock is occasionally struck in that part of the county at about 40 feet, but wells usually obtain water above the rock.

At Chapin the shafts or borings for coal pass through about 12 feet of loess, beneath which is a sheet of till extending to the rock, which is entered at 40 to 50 feet. Wells in several instances have been sunk entirely through the drift, but they usually obtain water at about 20 feet.

At Jacksonville wells are usually obtained at 20 to 40 feet, but the public water supply is from two deep artesian wells, one of which is 2,373 and the other 3,028 feet in depth. The wells are situated on low ground, about 30 feet below the level of the Chicago and Alton depot, and water will rise a few feet above the surface. In the shallower well it is stated to rise 15 feet and in the deeper one 30 feet above the well mouth. Attention is here called to an error which appears in the present author's paper in the Seventeenth Annual Report, the head at the deep well being given as 30 feet below the surface, instead of 30 feet above. The drift at the artesian wells is about 140 feet in thickness and consists mainly of till. A boring for coal east of the city penetrated 154 feet of drift, mainly till, except about 10 feet of sand at the bottom.

There is a series of drift knolls leading from Jacksonville southwestward 3 or 4 miles on which several wells have been obtained at depths of 40 to 50 feet. They are almost entirely through till, the lower half being a blue till.

At Prentice a coal shaft penetrates 85 feet of drift, the greater part of which is a blue till. In the lower ten feet a sandy clay containing a log was passed through.

At Alexander wells are usually obtained at depths of 20 to 40 feet, but one at the elevator reached a depth of 95 feet and did not enter rock. Its section is as follows:

Section of well at elevator in Alexander, Illinois.

	Feet.
Loess	10
Yellow till	10
Blue till with thin sand beds	75

A well near Alexander, on the farm of Isaac Tyndall, was sunk to a depth of 1,000 feet without obtaining a flow. Another well was sunk to a depth of 320 feet. Each of the wells yields a small amount of gas, which is struck in Coal Measures strata. The drift at these wells is about 90 feet in depth, as follows:

Section of drift in Tyndall well near Alexander, Illinois.

	Feet.
Soil and yellow clay	25
Gray pebbly clay	26
Blue clay	25
Clays of variable color	15
Total drift	90

At Waverly wells are 20 to 50 feet in depth, and the deeper ones enter rock near the bottom. The loess in that vicinity is only 6 feet in depth. The drift is mainly yellow till, though there is blue till near the base.

In the vicinity of Franklin rock is usually entered at about 35 feet, but wells are often obtained above the rock.

SANGAMON COUNTY.

GENERAL STATEMENT.

Sangamon County, situated near the center of the State, contains Springfield, the State capital, which is also the county seat. It has an area of 860 square miles. The northeastern portion of the county is traversed in a westward course by the Sangamon River, and this stream with its tributaries drains nearly all of the county. The drainage from the western and southern portions of the county is northeastward, there being a rapid descent in that direction. The county is well drained, and yet the valleys of most of the streams are very shallow. A coating of loess about 8 feet in average depth caps the glacial drift, and aids greatly in the ready absorption of the excess of rainfall.

The drift is generally of moderate depth, the distance to rock being seldom more than 50 feet. Where it is mainly till, wells are frequently sunk into the underlying Coal Measures for water, the supply from the drift being weak. The conspicuous development of Sangamon soil between the loess and till is discussed on preceding pages.

INDIVIDUAL WELLS.

The public water supply for the city of Springfield is obtained from infiltration wells sunk to a depth of about 25 feet on the banks of the Sangamon River. Private wells are largely discontinued, but may be obtained at depths of 25 feet or less.

In the northwest part of the county, near Pleasant Plain, the drift is 60 to 80 feet in depth, as shown by coal shafts, but wells are usually obtained at 20 to 40 feet.

In the northern part of the county the drift is 40 to 60 feet in depth, but wells are usually obtained without entering the rock.

In the eastern part several coal shafts and a few of the wells enter rock at about 60 feet. At Illiopolis rock is struck at 54 feet, and at Dawson at 60 feet. Southeast from Illiopolis, near the Sangamon River, records of two wells were obtained which penetrated about 80 feet of drift.

In the southern part, near Lowder, although the altitude is the highest in the county, rock is frequently entered at about 20 feet. This area of thin drift is a continuation of that noted in southeastern Morgan County.

In the western part of the county the distance to rock ranges from 20 to at least 75 feet. Near New Berlin the rock is entered at 40 or 50 feet. At Bates a well at the elevator, 70 feet in depth, did not reach rock. A well at the elevator in Curran also reached a depth of 70 feet without entering rock, but within 2 or 3 miles south of Curran wells enter rock at 20 or 30 feet.

CHRISTIAN COUNTY.

GENERAL STATEMENT.

Christian County is situated southeast of Sangamon and has an area of 710 square miles, with Taylorville as the county seat. It is drained chiefly by the South Fork of Sangamon River, which leads northwestward through the county. The main Sangamon River forms the north border of the county. The character of the drainage and the coating of loess are similar to the same features in Sangamon County already discussed.

The drift is seldom less than 60 feet, and in places is more than 100 feet in thickness, and consists largely of blue till. The occurrence of peat and muck at the base of the loess is quite common, as indicated on page 126. Throughout the county wells are usually obtained at depths of 20 to 30

feet. The data concerning the distance to rock are obtained largely through coal shafts and borings.

INDIVIDUAL WELLS.

At Mount Auburn, which is situated on a knoll in the north part of the county, wells penetrate a brown, sandy clay to a depth of about 30 feet before entering blue till. On the bordering plain blue till is found at 20 to 25 feet, but wells are usually obtained without entering it. The drift in that vicinity is at least 80 feet in depth.

Near the center of the county, in the vicinity of Taylorville, wells are frequently found at depths of only 15 feet, in sandy beds at the base of the loess. In the city of Taylorville, however, they are usually sunk to depths of 20 to 40 feet. The public water supply is from an open well 30 feet in diameter and 30 feet in depth. The amount of water is so great in this vicinity that much difficulty is experienced in sinking coal shafts. The Taylorville coal shaft has the following section of drift:

Section of drift in the Taylorville coal shaft.

	Feet.
Surface clay	13
Sand and gravel	24
White clay	3
Black gummy clay	4
Bowlder clay	17
Sand and gravel	15
Sand	15
Greenish clay	12
Clay and gravel	12
Sand and gravel	11
Total drift	126

At Pana the coal shaft is reported by Worthen to have penetrated two buried soils, but the writer finds that his upper soil is simply wood embedded in till. The lower is a black muck. The import of this section, together with similar sections at other points has already been discussed (p. 107 et seq.). The wells in this city range from 18 to about 50 feet in depth. The waterworks supply is from wells 45 to 48 feet deep, in part 3 inches and in part 6 inches in diameter. These wells afforded, during the season of drought in 1895, an average daily consumption of 215,000 gallons. A boring was sunk at this city to a depth of 2,507 feet, but found only a weak supply of brackish water after entering the rock.

At Morrisonville the public water supply is obtained from large wells excavated to a depth of 25 or 30 feet. During the drought of 1894 and 1895 only about 300 barrels a day could be obtained from this source, where fully twice that amount was needed. Mr. H. N. Herdman, chairman of the waterworks committee, estimates that private wells in the village have an average yield of about 10 barrels a day in seasons of drought.

At Palmer a coal shaft penetrates 60 feet of drift, as follows:

Section of coal shaft at Palmer, Illinois.

	Feet.
Loess and yellow till	16
Hard gray till	22
Soft brown clay	7
Sand	10
Gravel	1
Pebbly clay	4
Total drift	60

At Miller Station rock is entered at about 60 feet, or at nearly the same elevation above tide as at Pana. The drift is largely gray till.

MACON COUNTY.

GENERAL STATEMENT.

Macon County is situated in the central part of the State, with Decatur as the county seat, and has an area of 780 square miles. The Sangamon River traverses it nearly centrally from east to west, and there are no other large streams within the limits of the county. The greater portion of the county lies within the limits of the Wisconsin drift, the outer moraine formed at the Wisconsin stage of glaciation having a southward course through the western part of the county. The portion occupied by the Wisconsin drift stands about 100 feet above the plain on the west, but is far less perfectly drained. Not only are drainage lines less perfect, but the loess, which constitutes so important an absorbent for water in counties to the west, is absent or is represented only by a thin coating, probably drifted by the wind.

The thickness of the drift is known at but a few points, and these, together with sections of deep wells which do not reach rock, indicate that the average thickness of the drift exceeds 100 feet. The Wisconsin drift consists largely of a soft blue till, readily distinguished from the harder

gray or blue tills of the earlier sheets beneath it and which extend over the country to the west.

Tubular wells are often sunk in the portion of the county covered by the Wisconsin drift to a depth of 100 to 150 feet, and occasionally to greater depths without reaching rock. A large number of wells, however, are obtained from this drift sheet at depths of but 20 to 40 feet. On the plain outside the limits of the Wisconsin drift the wells are often obtained at but 12 to 15 feet, and they seldom exceed 25 feet in depth.

INDIVIDUAL WELLS.

At Niantic, on the plain in the western part of the county, wells are usually obtained in sand and gravel at a depth of 15 feet. A coal shaft at this village penetrates the following beds of drift:

Section of drift beds in coal shaft of Niantic, Illinois.

	Feet.
Soil and brown clay	11
Sand and gravel	4
Till of grayish color	25
Hard blue till	10
Soft clay	15
Hard gray till	10
Soft clay of brown color	7
Total drift	82

At Harristown, on the crest of the moraine east of Niantic and about 90 feet higher, several tubular wells have been sunk to depths ranging from 75 to 152 feet. The deepest, at the residence of Dr. John Connelly, has the following section:

	Feet.
Yellow till	15
Soft blue till, about	100
Hard grayish-blue till	37
Gravel and water at bottom.	
Total	152

In several instances the wells near Harristown appear to obtain their supply from the base of the Wisconsin drift, just below the soft blue till, at a depth of 100 to 110 feet. The few which are sunk deeper usually enter a harder till, as in the section just noted. East from Harristown, toward Decatur, the wells are often sunk to depths of 85 to 110 feet, mainly through a soft blue till. The elevation is a few feet lower than on the crest of the moraine at Harristown, and the wells probably reach the bottom of the Wisconsin drift.

The city of Decatur obtains its public water supply by pumping from the Sangamon River. The city engineer reports that the wells of that city obtain their strongest supply of water at a depth of about 100 feet in beds of gravel below blue clay, and that the water from these wells will rise within 20 feet of the top. He estimates the capacity of a good well to be about 20 barrels a day. Coal borings at Decatur, reported in the Geology of Illinois, enter rock in one instance at 110 feet and in another at 140 feet. The section of the air shaft, taken from the Geology of Illinois, which appears on page 204, indicates the variable structure of the drift. The shaft is located near the Sangamon River bluff.

At Maroa, in the north part of the county, the strongest wells are about 100 feet in depth, in gravel below till. This village has waterworks, recently constructed, which obtains its supply from gravel at a depth of 85 to 100 feet. At the neighboring village of Forsythe several good wells are obtained at 35 to 45 feet.

At Macon a well 120 feet in depth furnishes the public water supply. It terminates in gravel below a thick sheet of till, and the well is practically inexhaustible. Water rises within 60 feet of the surface, and it is stated by residents that the water rose to that level in less than five minutes after the water bed was struck.

The well at Blue Mound from which the public water supply is pumped was sunk to a depth of 213 feet without reaching rock, mainly through a hard blue till. As this village stands on the plain outside the Wisconsin drift sheet, the great thickness of drift here penetrated belongs to an earlier stage of glaciation. The principal part of the water is obtained within 40 feet of the surface, and wells in that vicinity are 15 to 40 feet deep.

MOULTRIE COUNTY.

GENERAL STATEMENT.

Moultrie County is situated southeast of Macon, in the east-central part of the State, with Sullivan as the county seat, and has an area of 340 square miles. The Kaskaskia River crosses the southeastern part in a westward course, and most of the county is tributary to that stream. Much of the surface is flat and poorly drained, the county being situated within the limits of the Wisconsin drift, where drainage lines are generally immature.

The thickness of drift is known only at the village of Sullivan, where it is about 200 feet. Borings in neighboring counties also penetrate nearly as great an amount of drift. It therefore seems probable that the thickness at Sullivan is not much above the average for the county. Wells in this county enter a soft blue till at 10 or 15 feet, which, like that of the neighboring counties, Platt and Macon, belongs to the Wisconsin drift. It probably extends to the level of the plain outside the Wisconsin drift sheet, which is nearly 100 feet lower than the general elevation of this county. Few records of wells were obtained, though it was ascertained that while wells are usually but 30 or 40 feet deep, not a few are sunk to depths of over 100 feet.

INDIVIDUAL WELLS.

At Sullivan the strongest wells are obtained at a depth of 100 to 125 feet in sand beds below till, and the waterworks are supplied from a well of this class. A coal boring at or near Sullivan, made by Mr. John Patterson, is reported to have struck a soft sandstone at about 200 feet, but a well boring at Sullivan, made by Mr. Patterson, is reported in the Geology of Illinois to have reached a depth of 210 feet without entering rock and to have terminated in sand below clay. Veins of water were struck at 15 feet, 105 feet, and 180 feet. The last vein struck has a head 15 feet below the surface.

At Dalton there is a village well 110 feet in depth, which obtains its main supply from about 70 feet.[1] Several wells in this vicinity are 70 to 85 feet in depth and a few about 100 feet. They reach the base of the Wisconsin drift at about 65 feet, below which there is sandy material often associated with a black mucky soil. Beneath this sandy material is a harder till than the Wisconsin. The deepest wells in that vicinity are 150 feet, and none strike rock.

At Bethany wells are often sunk to a depth of 70 feet before reaching a good supply of water. The Wisconsin drift here is only about 40 feet, beneath which there is a greenish clay associated with a black muck. This is underlain by a hard till, in which there are gravelly beds yielding water. The deepest wells are 140 feet and do not enter rock.

[1] The Manual of American Waterworks (1897) reports that the public water supply at Dalton is obtained from a shallow well requiring a pump but 22 feet in length. This is evidently a mistake, since no waterworks had been constructed or were contemplated at the time of my visit in June, 1897.

DOUGLAS COUNTY.

GENERAL STATEMENT.

Douglas County is situated in the east-central part of the State, with Tuscola as the county seat, and it has an area of 410 square miles. Its western portion is crossed in a southward course by the Kaskaskia River, and the east-central portion by the Embarras River. The surface is generally very level and imperfectly drained, except on the immediate borders of the streams just mentioned. A small drift ridge belonging to the Champaign system traverses the northeast part of the county, but it has a general relief of only 20 to 30 feet above the bordering plain. A similar small ridge crosses the southeast corner of the county. The surface of these ridges is nearly as smooth as that of the bordering plains, and is imperfectly drained.

The thickness of the drift in this county has been ascertained at but one point, Tuscola, where one well entered rock at 174 feet and another at 179 feet. But at Oakland, just across the county line, in Coles County, rock is entered at only 50 feet. The drift, like that of the counties to the west, just discussed, consists mainly of a soft blue till as far as wells have penetrated. In the wells at Tuscola the drift was in the main a blue till. Wells 60 to 75 feet in depth are common in this county, and a few have been sunk to depths of 100 feet or more.

INDIVIDUAL WELLS.

At Arcola the public water supply is from wells about 50 feet in depth, and records of several wells were obtained in the vicinity of that village which have a similar depth. Two wells a few miles southeast of Arcola are reported to have entered a swampy muck below blue till at about 50 feet, and beneath this a till was found harder than that above the muck. One well at Morris Bradford's reached a depth of 68 feet and one at E. Bradford's a depth of 75 feet.

At Tuscola a deep well has been sunk with a view to obtaining artesian water for the waterworks, but at last reports the well was incomplete and waterworks had not been established.[1] The wells in the vicinity of Tuscola are obtained at a depth of about 30 feet, but none are considered of sufficient strength to supply the waterworks.

[1] Manual of American Waterworks, 1897.

EDGAR COUNTY.

GENERAL STATEMENT.

Edgar County is situated near the middle of the east boundary of the State and has an area of 630 square miles, with Paris as the county seat. It is crossed by no large streams, the drainage being entirely through small creeks. Those in the eastern part drain eastward to the Wabash, those in the western part are tributary to the Embarras, while the drainage of the southern portion is divided between the tributaries of the Embarras and small streams leading directly to the Wabash.

The northern part of the county is occupied by the Champaign morainic system, while the southern portion is crossed by the Shelbyville morainic system. Between these morainic systems there is a very flat area dotted with occasional low knolls or ridges of drift. South of the limits of the Wisconsin drift there is a low plain which touches the borders of this county and which is markedly more eroded than the more elevated plain north of the outer moraine, a feature which testifies to its longer exposure to agencies of erosion.

The drift of the moraines and the plain between them consists largely of a soft blue till, though portions of the outer moraine have a gravelly constitution. The plain outside the outer moraine is underlain by a harder till than that forming the body of the moraine. It is also capped by a silt which is correlated with the loess, but the moraine and district to the north are nearly free from silt capping.

The thickness of the drift along each of the moraines is 100 feet or more, but on the plain between the moraines rock is in places entered at 50 feet or less, the drift being much thinner than in counties to the west. The rock surface appears to be generally higher in Edgar County than in neighboring counties on the west.

Wells are generally obtained in this county at depths of 20 to 40 feet and, so far as ascertained, very few exceed 60 feet. Those which enter rock usually find water within a few feet. The majority, however, obtain their supply above the rock.

INDIVIDUAL WELLS.

The public water supply at Paris is obtained from a well 60 feet deep, which terminates in gravel below till. The private wells in the city and

vicinity are usually obtained at depths of 20 to 40 feet. A boring at Sanford, near the State line, east of Paris, whose section is given on page 201, entered rock at 147 feet.

At Dudley wells are obtained at about 25 feet and are largely through a sandy drift. Between Dudley and Kansas and also to the north of the latter village wells are reported to have passed through a soil below till at 35 to 40 feet.

At Kansas wells are usually 20 to 25 feet and occasionally 40 feet in depth. They are obtained in gravel below blue till. Good wells are estimated to yield about 30 barrels of water a day.

Near Isabel wells occasionally reach a depth of 50 or 60 feet without entering rock. The majority of wells, however, are much shallower. A short distance east of Isabel rock is encountered at a depth of only 25 feet, and wells in the central and eastern parts of the county not infrequently enter rock at 25 feet or less.

On the plain outside the Wisconsin drift wells are usually obtained at about 30 feet and seldom enter the rock. They are largely through a hard till.

CLARK COUNTY.

GENERAL STATEMENT.

Clark County is situated on the eastern border of the State, immediately south of Edgar, a portion of its east border being formed by the Wabash River. It has an area of 510 square miles, with Marshall as its county seat. The eastern portion of the county drains directly to the Wabash, but the western half is drained southward through Hickory Creek, a tributary of the Embarras. The outer moraine of the Wisconsin drift covers a few square miles in the northwest corner of the county. Aside from this the drift of the county belongs to the earlier stages of glaciation. Although the surface was originally very level, drainage lines are sufficiently well developed to remove the surplus rainfall more rapidly than on the flat areas occupied by the Wisconsin drift. The drift has a capping of the compact phase of the loess, called white clay, whose depth is but 5 or 6 feet. As previously indicated, this clay is separated from the underlying till by a black soil.

The drift of this county is largely a hard till which is brownish yellow at top, but changes to a greyish blue color at a depth of 15 or 20 feet.

Wells are usually of sufficient strength for household or farm use, but Mr. J. T. Lafferty, of Martinsville, an old resident of the county, states that the strongest wells seldom yield more than 10 barrels a day, and a large number will not afford more than one barrel. Wells are usually obtained at a depth of 15 or 20 feet from pockets or thin beds of gravel or sand associated with the till. In portions of the county wells have been sunk to depths of 40 feet or more, and such wells usually obtain their supply from gravel below blue till. In the vicinity of Marshall, however, sandstone is entered at about 20 feet, and wells are obtained after penetrating it a few feet.

INDIVIDUAL WELLS.

The wells at Marshall which enter sandstone are estimated to yield, in some cases, 100 barrels a day, and many of them are but 25 feet in depth.

In the vicinity of Martinsville a few wells have been sunk to a depth of 70 or 80 feet, but they are usually obtained at 15 or 20 feet.

At Casey the deepest wells are about 100 feet, but the great majority are between 18 and 25 feet in depth.

On the Wabash bottoms, in the southeast part of the county, wells are usually obtained at about the level of the river. On the higher terraces they need to be sunk 50 or 60 feet. They penetrate fine gravel or sand.

COLES COUNTY.

GENERAL STATEMENT.

Coles County is situated in the east-central part of the State, with Charleston as the county seat, and has an area of 520 square miles. The Kaskaskia River passes southwestward across its northwest corner, and the Embarras River passes southward through the eastern part of the county. The greater part of the county is tributary to the latter stream, but is imperfectly drained, like the neighboring counties on the north and west already discussed. The Shelbyville morainic system crosses the southern part of the county in an east-to-west course, leaving but a few square miles in the extreme southeast and southwest corners outside its limits. This morainic system has a breadth of 5 or 6 miles and a relief of 75 to 100 feet above the plain south of it. It stands only 30 to 50 feet above the plain on the north.

The Wisconsin drift sheet in this county, as in neighboring counties already discussed, consists largely of a soft blue till, while the underlying sheet of drift is a harder till. Along the Embarras River there are exposures of the harder till beneath the Wisconsin drift, and this harder till is capped by a white clay, as in the districts outside the limits of the Wisconsin drift.

In the eastern portion of the county rock is occasionally entered at 45 to 50 feet, and is exposed extensively along the Embarras River in the southern part of the county. The thickness in the western half of the county is greater, being in places not less than 150 feet. Wells are usually obtained without entering the rock, and in the western part of the county but few reach the bottom of the Wisconsin sheet of drift.

INDIVIDUAL WELLS.

At Oakland, in the northeast part of the county, the wells are usually about 20 feet in depth. But a well at the mill reached a depth of 120 feet, entering rock at 50 feet.

Northwest from Fairgrange several wells have been sunk to depths of 60 to 120 feet without entering rock. They usually pass from a soft to a hard till at a depth of 50 or 60 feet. This is thought to be the depth of the Wisconsin drift sheet in that locality.

At Charleston the waterworks are supplied by pumping from the Embarras River. Wells are usually obtained from sand and gravel below till at a depth of 20 to 40 feet. A well in the northern part of this city reached a depth of 127 feet without entering rock, but a boring for oil made some years since is reported in the Geology of Illinois to enter rock at 55 feet. The section of drift is as follows:

Section of boring at Charleston, Illinois.

	Feet.
Soil and yellow clay	18
Sand and gravel	6
Blue clay	16
Bowlder clay	15
Total drift	55

At Mattoon the public water supply is obtained from sand and gravel below till at a depth of 60 to 70 feet. The private wells in this village are usually obtained at 15 to 30 feet. A coal boring is reported to enter rock at about 100 feet (see p. 202).

At Lerna, which is situated on the crest of the outer moraine of the Wisconsin drift, wells have occasionally reached a depth of 100 feet without entering rock. One made by Mr. Todd, one-half mile northwest of the village, and another by Mr. Farris in section 11, each have a depth of 100 feet and are mainly through blue till.

A well near Farmington, made by Mr. T. Allison, reached a depth of 132 feet without entering rock, mainly through blue till. East from this well, in the Embarras Valley, rock is exposed up to a level within 75 feet of that of the well mouth.

At Diona, on the plain outside the Wisconsin drift sheet, wells are obtained at a depth of only 12 feet, and are mainly through gravel.

CUMBERLAND COUNTY.

GENERAL STATEMENT.

Cumberland County is situated south of Coles, in the east-central part of the State, with Toledo as the county seat, and it has an area of 350 square miles. The Embarras River leads southward through the east-central part of the county and drains its eastern half. The western part is tributary to the Little Wabash River, which leads southward near the county line. This county is strikingly in contrast with Coles County on account of the absence of the Wisconsin drift sheet, which covers only a few square miles on its north border. Its surface is covered with the deposit of white clay which is so prevalent in southern Illinois outside the limits of the Wisconsin drift. This clay absorbs water so slowly on the interfluvial tracts of Cumberland County that most of the water not removed by the streams is evaporated. The surface is very level, and this feature works to the disadvantage of the development of drainage systems. There is, however, a much more mature system of drainage here than on the Wisconsin drift sheet in Coles County, a feature which points strongly to the comparative freshness of the latter sheet and recency of its deposition.

The thickness of the drift is known at but a few points, and these are in the vicinity of the Embarras River. In places the rock occurs along this river at a level only 30 or 40 feet below the level of the uplands, but in other places wells near the river show that the drift extends fully 50 feet below the bed of the stream, or over 100 feet below the level of the uplands. Beneath the white clay, which is usually but 4 or 5 feet in thickness, there is

a black soil formed at the surface of the till. The body of the drift appears to be generally a hard till oxidized to a yellowish color for a depth of about 12 to 15 feet, beneath which it has a blue-gray color.

The wells in this county, like those in Clark County, on the east, are usually of sufficient capacity to supply the needs of the residents, though they seldom yield more than 10 barrels a day. The till apparently has only local inclusions of sand and gravel, seldom of sufficient amount to furnish strong wells. The depth of wells rarely exceeds 40 feet, and the majority are only 10 or 15 feet. It is probable that they are largely filled from the well mouth by water running into them from the surface of the ground during rainy seasons.

INDIVIDUAL WELLS.

At Toledo the strongest wells are obtained at about 60 feet from gravel below till. At the bend of the Embarras River, about 5 miles northeast of this village, two wells situated on the terrace about 20 feet above the river are 67 and 71 feet in depth. They each penetrate about 20 feet of gravel, beneath which they are entirely in sand and do not strike rock. At the bluff of the river, east of these wells, the following section is exposed, which, it will be observed, is entirely different from the sections of the wells:

Section of bluffs of Embarras River, near Toledo, Illinois.

	Feet.
White clay	4
Soil and pale clayey subsoil	5
Brown till	10
Gray till	30

At Greenup the wells are usually obtained near the base of the drift, at a depth of about 30 feet. The rock in the vicinity of Greenup stands at an elevation nearly 50 feet above the Embarras River.

At Neoga, on the west border of the county, wells are usually obtained at about 15 feet. A boring for coal is reported to have entered rock at less than 40 feet, there being a bed of coal at that depth.

SHELBY COUNTY.

GENERAL STATEMENT.

Shelby County is situated southeast of the center of the State, immediately west of Cumberland and Coles counties. It has an area of 776

square miles, with Shelbyville as the county seat. The Kaskaskia River traverses the county in a north-and-south direction and drains nearly all its surface. A small area in the southeast part is tributary to the Little Wabash, and the northwest corner of the county is tributary to the Sangamon River. The Shelbyville moraine passes across the northeast part of the county making an abrupt turn at the city of Shelbyville from a westward to a northward course.

The portion of the county outside the Shelbyville moraine is generally plane, but the west part of the county is dotted with knolls of drift, some of which reach a height of over 100 feet and many are at least 50 feet.

In the portion of the county occupied by the Wisconsin drift there is a sheet of soft blue till 50 to 100 feet or more in depth, covering the harder till, which extends into the outlying districts. Exposures of the hard till beneath the Wisconsin drift are to be seen along the Kaskaskia River in the vicinity of Shelbyville. There are also along the stream near Shelbyville exposures of the white clay which covers the hard till.

The drift outside the Wisconsin sheet consists usually of till; but some of the knolls and ridges contain a large amount of gravel or sand. Rock is often entered in this district at a depth of 50 feet or less, except on the drift knolls and ridges, where the distance to rock is usually increased by the measure of the height of the knoll or ridge.

The wells are usually obtained without entering rock. Those on the Wisconsin drift are frequently sunk to depths of 75 or 100 feet, but those on the older sheet outside the limits of the Wisconsin drift seldom exceed 30 feet.

INDIVIDUAL WELLS.

At Moweaqua, on the plain outside the Wisconsin drift, in the northwest part of the county a coal shaft penetrates 65 feet of drift. The upper 22 feet is a comparatively soft clay, but the remainder is a very hard blue till. A well in process of excavation at the time the writer was there exposed the following section:

Section of well at Moweaqua, Illinois.

	Feet.
Loess or pebbleless yellow silt	8
Yellow clay with a few fine pebbles	7
Deeply oxidized till, very pebbly	9
Hard blue till at bottom.	

The Manual of American Waterworks, 1897, reports that the public water supply at Moweaqua is obtained from wells, but the depth is not given.

At Tower Hill a coal boring enters rock at 60 feet. Drift knolls in this village rise about 60 or 75 feet above the level of the ground at the point where this boring was made. The wells in the vicinity of Tower Hill are usually obtained at 20 feet or less, from beds of sandy clay overlying a hard blue till.

The public water supply at Shelbyville is pumped from the Kaskaskia River. Wells are usually obtained at depths of 30 to 50 feet from sand below till; in some cases they are obtained at the base of the Wisconsin drift.

At Cowden, near the south border of the county, wells are usually obtained at about 20 feet, just above the hard blue till. Rock is struck at 40 or 50 feet An exposure on the Kaskaskia bluffs, near Cowden, has the following section:

Section of bluffs of Kaskaskia River, near Cowden, Illinois.

	Feet.
White clay	5
Yellow clay with a few pebbles	3
Reddish-brown sandy till	6–8
Yellow till, blue in places	10–15
Hard blue till	20
Coal Measures shale at base of bluff.	
Total drift	45

At Stewardson, in the southeast part of the county, wells are usually obtained at 20 to 40 feet without entering rock, and similar conditions occur at Strasburg.

At the village of Windsor, which is located on the Shelbyville moraine, the village well penetrates 90 feet of soft till, apparently belonging to the Wisconsin drift, beneath which there is a harder till with sandy matrix. Water was obtained in sand at a depth of 127 feet. Several prospect borings have been made by Mr. Jerry Linnville at this village, which have reached depths ranging from 120 to 170 feet without entering rock. Gas was found in sand at 115 to 120 feet, and beneath this at about 135 feet a black muck was penetrated. Whether this muck was formed in a valley bottom in a stage just before the Wisconsin drift was deposited or is separated from the Wisconsin by a glacial deposit of greater age is not made

clear by the records of these borings. There appears, however, to be a deposit of sand extending from the base of the Wisconsin till sheet down to the bed of muck.

At the village of Findlay, in the north part of this county, several gas wells have been obtained at shallow depths, ranging from 45 feet to about 150 feet. One well only 45 feet in depth has furnished gas for a period of five years in sufficient amount to supply three stoves. Some of the wells pass through a thin bed of rock before obtaining gas, while others obtain it in the drift. The pressure is estimated to be about 12 pounds per square inch in the wells now in use, though in some cases a stronger pressure may be found since some have not been tested with a gauge.

MONTGOMERY COUNTY.

GENERAL STATEMENT.

Montgomery County is situated in the south-central part of the State, with Hillsboro as the county seat, and has an area of 702 square miles. The drainage is mainly southward through the several headwater forks of Shoal Creek, a tributary of the Kaskaskia River. The extreme north border of the county is tributary to the Sangamon River. There are narrow strips with flat, rather imperfectly drained surface on the divide between Shoal Creek and streams flowing north or west; but the greater part of the county has good drainage. The belts of knolls and ridges noted in southwestern Shelby County cross the eastern and central portions of Montgomery County, and also occur at a few places in the southern part of the county. The best defined belt is in the northeastern part, immediately east of Witt, Nokomis, and Ohlman. A ridge there rises to a height of nearly 100 feet above the bordering plains, and is maintained continuously for several miles.

On the plane portions of the county a hard blue till is usually entered at 15 or 20 feet, after penetrating beds of loess and yellow till. Many of the wells are obtained above this blue till. On the knolls and ridges the distance to the blue till is apparently greater than on the plains. A few wells have entered it at about 40 feet, after penetrating a series of clay, sand, and gravel beds of brown or yellow color. In a few places on the plain the drift has been found to have a thickness of more than 100 feet. On the prominent knolls and ridges it probably exceeds that amount.

Rock is often entered at 50 to 75 feet, and is exposed along the streams at a similar level below the upland plain. Occasionally the thickness of the drift is but 10 or 20 feet, as at Harvel and Witt, noted below.

INDIVIDUAL WELLS.

At Thomasville, in the extreme north part of the county, the wells enter rock at a depth of about 30 feet, but are usually obtained near the base of the drift. At Harvel rock is entered at 14 to 20 feet.

At Nokomis, in the eastern part of the county, the drift is about 100 feet in depth. The Manual of American Waterworks reports that the public water supply is obtained from driven wells, but the depth is not given. In the vicinity of Witt, a few miles south of Nokomis, rock is entered at about 10 feet, but wells are obtained without difficulty near the top of the rock.

At Hillsboro the public water supply is obtained from springs. Wells are usually obtained at depths of 18 to 25 feet just above the blue till. They occasionally reach a depth of 60 feet. A coal boring made near this city shows a complex series of drift beds, as follows:

Section of coal boring near Hillsboro, Illinois.

	Feet.
Pale silt and pebbly brown clay	14
Bluish-gray till	23
Sand	1
Blue-gray till	16
Yellow clay	7
Sand and gravel	20
Blue till	26
Sand and gravel	16
Total drift	123

In the vicinity of Butler rock is struck at about 50 feet and the drift is mainly till. Wells are usually obtained at 20 feet or less.

The city of Litchfield obtains its public water supply from Shoal Creek. A coal boring at this city penetrated 75 feet of drift. Wells are usually obtained at 25 to 40 feet. About 1½ miles southeast of Litchfield several deep wells have been drilled for oil, a small quantity of oil being obtained at about 675 feet. The drift at these wells is 52 to 60 feet, and mainly a hard blue till.

On the plane tracts in the southeastern part of the county wells are usually obtained at about 15 feet just above the blue till. On neighboring

knolls they are often sunk to depths of 40 feet or more without encountering blue till.

A well on a drift ridge in the east part of the county in sec. 17, T. 10, R. 1 W., reached a depth of 97 feet without entering rock and was mainly through a hard clay of yellowish brown color. Beds of dry sand and cobblestone were also penetrated. A well on a neighboring section (sec. 20) obtained water in cobble below brown till at a depth of 40 to 47 feet.

MACOUPIN COUNTY.

GENERAL STATEMENT.

Macoupin County is situated southwest of the center of the State, immediately south of Sangamon and west of Montgomery County. It has an area of 864 square miles, with Carlinville as the county seat. The county is traversed nearly centrally from east to west by Macoupin Creek, which is the only stream of importance found within its limits. The southeast part is drained southward through Silver, Cahokia, and Piasa creeks and Wood River. The northwest portion of the county drains westward through Apple Creek. Narrow strips of imperfectly drained land occur along the divide between Macoupin Creek and streams flowing southward, but the greater portion of the county is well drained. It has a thin deposit of silt somewhat less porous than typical loess, yet it absorbs the excess of rainfall more rapidly than the white clay districts to the east.

The drift surface is generally plane, though occasional knolls 20 to 30 or even 50 feet in height occur. The largest ones noted are about 5 miles east of Carlinville, on the borders of Macoupin Creek. The thickness of the drift is apparently less on the water partings in the north and south parts of the county than near Macoupin Creek in the central portion. It is probable as noted above that this stream follows approximately the line of a preglacial valley.

The wells are usually found at depths of 25 to 50 feet, many of them obtaining their supply above blue till, but others in sand and gravel beneath it. The wells and natural exposures indicate that a sheet of hard blue till is generally present in this county as in Montgomery County, setting in at about 20 feet and extending to the rock.

INDIVIDUAL WELLS.

At Virden, in the north part of the county, wells are usually obtained at 15 to 25 feet from sandstone, the drift being very thin in the vicinity of that village. The best wells are estimated to yield 50 barrels per day, but usually a well will afford only a small fraction of that amount. During the drought of 1894–95 so many of the wells became dry that fears of a water famine arose.

At Modesto, also near the north border of the county, rock is entered at 25 or 30 feet, but wells are usually obtained near the base of the drift.

In the vicinity of Scottville, in the northwest part of the county, the drift is about 50 feet in depth and usually affords abundance of water for wells.

At Girard and Nilwood, in the northeastern part of the county, the coal shafts enter rock at about 70 feet. Wells are usually obtained from thin beds of sand at about 20 feet. The drift is mainly a blue till.

At Carlinville the public water supply is pumped from Macoupin Creek. A coal shaft enters rock at about 75 feet. In the Geology of Illinois an instance of the penetration of a thick sheet of drift near this city is noted. A boring in Macoupin Creek Valley, made by T. L. Loomis, reached a depth of 160 feet without entering rock. It was mainly through blue till.

At Medora a coal boring is reported in the Geology of Illinois to have the following section:

	Feet.
Yellow till	24
Blue till	30
Gravel	20
Total drift	74

In the vicinity of Brighton, in the southwest part of the county, rock is struck at about 30 feet, but wells are usually found in the drift.

At Bunker Hill wells are usually obtained at 20 to 30 feet in sand below till. They are estimated to have an average daily yield of about 5 barrels. A coal shaft in this village is reported in the Geology of Illinois to enter rock at 28 feet.

At Staunton the public water supply is obtained by impounding water

on tributaries of Cahokia Creek. Private wells are obtained usually at 16 to 20 feet. Coal shafts penetrate 90 to 110 feet of drift, mainly blue till. The drift is much thinner northwest from Staunton than at this village, rock being exposed along Cahokia Creek at a level only 25 feet below the bordering uplands. At the villages of Gillespie and Dorchester rock is entered at 25 to 40 feet, or at a higher elevation than the surface of the ground in Staunton, the altitude of the railway station at Gillespie being 60 feet and at Dorchester 45 feet above Staunton.

GREENE COUNTY.

GENERAL STATEMENT.

Greene County is situated on the east side of the Illinois River, a short distance above its mouth, and has an area of 544 square miles, with Carrollton as the county seat. It is drained westward principally by Apple Creek and Macoupin Creek, the former leading through the north-central and the latter through the southern portion of the county. Each of these streams flows in a trough-like depression, which probably was the line of a preglacial stream. The divides on either side of these depressions rise 50 or 75 feet above the level of the drift surface on the borders of the creeks, and they apparently have a thinner coating of drift than the trough-like depressions. Wells, however, are seldom sufficiently deep to test the thickness of the drift. The county is well drained by streams and has also a coating of loess which absorbs the rainfall rapidly.

There are a few drift knolls in the western half of the county, the largest of which rise about 50 feet above bordering plane tracts. There are not such well-defined ridges in this county as in Pike and Adams counties, but it is thought that these knolls in Greene County mark the continuation of the belt of drift ridges noted in those counties.

The drift of Greene County consists largely of blue till, as in counties to the north and east. The few borings which have reached rock penetrate about 50 feet of drift, and this is probably about the average for the county. Preglacial valleys may perhaps materially increase the average. The wells are usually obtained before entering blue till at a depth of but 15 or 20 feet. In the Illinois bottoms they are often sunk to a depth of 40 feet, mainly through fine sand.

INDIVIDUAL WELLS.

At Roodhouse, in the north part of the county, at an altitude about 650 feet above tide, wells obtain water at 15 to 25 feet in a gravel below clay. A coal boring is reported in the Geology of Illinois to have penetrated 75 feet of drift, but one near the mill entered rock at 35 feet after penetrating the following beds:

Section of drift in a well at the Roodhouse mill.

	Feet.
Loess	10
Yellow till	15
Blue till	10
Total	35

At Whitehall, 4 miles south of Roodhouse and at 75 feet lower elevation, the drift is shown by several wells to have a thickness of about 50 feet. In parts of the village strong wells are obtained at 20 feet, but in other parts they are sunk to the rock.

At Carrollton the public water supply is from a well 1,330 feet in depth, which terminates in the St. Peter sandstone. It has a head 50 feet below the surface, or 565 feet above tide. A peculiar series of beds were penetrated before the rock was entered, there being a black muck about 32 feet in depth immediately below the loess, and under this beds of yellow and red clay extending to the rock, no typical till being found. Rock was entered at about 60 feet.

At Greenfield the wells are 18 to 30 feet in depth and obtain their supply from gravel or from clay. The usual depth is about 20 feet.

CALHOUN COUNTY.

GENERAL STATEMENT.

Calhoun County occupies the narrow strip of land between the Illinois and Mississippi rivers just above their junction. It has an area of 260 square miles, and Hardin is the county seat. The elevation is in places 350 feet above the neighboring streams, and as the neck of land between the streams is scarcely 6 miles in average width, the topography is very rugged compared with the general topography of Illinois. Glacial drift is found only in a small portion of the county, and it is thought by Professor Salisbury,

who has examined the county in some detail, that the greater part of it has never been glaciated.[1]

The upland portion of this county is sparsely settled, and in consequence few wells have been made. Cistern water furnishes those who have not the money to sink deep wells. In the Illinois and Mississippi bottoms there are rich farms, and the wells obtain water at depths of 30 to 60 feet in the sand of the river bottoms.

JERSEY COUNTY.

GENERAL STATEMENT.

Jersey County is situated on the east side of the Illinois River, extending to the mouth of that stream and a few miles down the Mississippi. It has an area of 360 square miles, with Jerseyville as the county seat. The northern part of the county is tributary to Macoupin Creek. The central portion drains westward through Otter Creek to the Illinois River. The southeastern portion drains southward through Piasa Creek to the Mississippi River. These streams afford good drainage. There is also a coating of loess which absorbs the rainfall rapidly.

Along the southern border of the county an elevated ridge formed by an upheaval of the rock strata rises in places to an altitude of 400 feet above the Illinois and Mississippi rivers, that flow along its base, and nearly 200 feet above the portion of the county to the north. Aside from this ridge the features of Jersey County are quite similar to those of Greene County. The northern portion slopes to the trough-like depression occupied by Macoupin Creek. A low ridge having rock at slight depth leads westward past Jerseyville, separating the drainage basin of Macoupin Creek from the basins of Otter and Piasa creeks. A few drift knolls and ridges occur in the western and southern parts of the county, the highest of which rise perhaps 75 feet above bordering plains, and which are a continuation of the belt in western Greene County, noted above. The belt of knolls is traceable nearly to the Mississippi bluffs south of Newbern, in the southern part of the county.

The drift, as in counties to the north and east, consists mainly of till. Its thickness ranges from 20 feet or less up to fully 100 feet. Records of eight borings which reach rock show an average of 30 feet, but preglacial

[1] Proc. Am. Assoc. Adv. Sci., Washington meeting, 1891, pp. 251-253.

valleys are liable to increase the average much beyond this amount. The drift is sufficient to greatly obscure the preglacial valleys and ridges.

Wells are ordinarily but 20 or 30 feet in depth, being obtained usually before entering the blue till. On the bottoms of the Illinois and Mississippi they are obtained at about 30 feet in sand and gravel.

INDIVIDUAL WELLS.

At Fieldon, in the western part of the county, rock is struck in wells at about 25 or 30 feet, and the best wells are obtained from this source at depths of 40 to 60 feet.

At Otterville the wells are from 14 to 35 feet in depth, and usually obtain water without entering rock. A section on Otter Creek bluff, near this village, reported in the Geology of Illinois, is as follows:

Section of bluff of Otter Creek, near Otterville, Illinois.

	Feet.
Yellowish brown clay (mainly loess)	16
Sand and gravel with bowlders	30
Blue clay	15
Total	61

The writer found a similar section on a ravine southwest from Fieldon, and there the blue clay at the base is a typical till.

At Beatty's Mound, between Otterville and Jerseyville, a well reached a depth of 65 feet without entering rock. The mound or drift knoll stands about 40 feet above the bordering plain. Wells on the plain north of the mound enter rock at about 30 feet.

At Jerseyville the public water supply is obtained from a well 2,003 feet in depth, which obtains most of its supply from the St. Peter sandstone at 1,400 to 1,600 feet. The water rises within 100 feet of the surface, or to 562 feet above tide, and the well will yield by pumping 200 gallons per minute from a 3-inch hole. An analysis of the water is presented in the Seventeenth Annual Report of this Survey (Part II, p. 827). It contains about 86 grains of salt per gallon, but is considered a palatable water. Rock is entered in that vicinity at about 20 feet, and wells are obtained either near the base of the drift or the top of the rock.

At Fidelity, in the eastern part of the county, wells are usually obtained at about 25 feet near the base of the drift, but a few pass into the underlying rock. In the eastern and southeastern parts of the county the drift is 20 to 35 feet in depth, and wells not infrequently enter the rock.

MADISON COUNTY.

GENERAL STATEMENT.

Madison County borders the portion of the Mississippi River between Alton and East St. Louis and extends a short distance northwest of the former city. It has an area of 740 square miles, with Edwardsville as the county seat. The eastern part of the county drains southward through Silver Creek, a tributary of the Kaskaskia. The northwestern portion is drained southwestward to the Mississippi through Cahokia Creek and Wood River. The drainage is generally sufficiently well developed to carry off the surplus rainfall rapidly, but there are small tracts in the eastern part of the county where drainage lines are not well developed, and the white clay which covers that region will not absorb the rainfall. The western half of the county is covered with a porous loess which absorbs water rapidly.

The southeastern part of the county is traversed in a southwestward course by a belt of drift ridges and knolls, which rise in places to a height of 50 or 75 feet above the bordering plain. A few knolls occur in the northeastern part of the county, which reach heights of 30 to 50 feet. In the western part of the county the surface is generally plane, though a knoll about 4 miles northwest of Edwardsville has a height of 30 or 40 feet, and knolls 10 to 15 feet in height are not rare.

The drift of this county, like that of Macoupin County, which joins it on the north, consists largely of a compact till. This till has been noted along the bluffs of the Mississippi as well as farther east, and the entire county appears to have been heavily glaciated. Striæ have been found in several places in and north of Alton, within 1 or 2 miles of the Mississippi River. The average thickness of drift in fifteen borings which reach the rock is found to be 40 feet. As this does not include borings which have been made in preglacial valleys, the average for the county probably is somewhat greater than 40 feet.

Wells are often obtained at depths of 20 to 25 feet without entering a blue till, and they very seldom need to be carried into the rock. Wells furnishing 20 barrels per day may usually be obtained from the drift, both at shallow and greater depths. Wells are often sunk below the first water vein in order to guard against contamination, for the porous loess of the

western part of the county offers a medium for ready transmission of impurities.

INDIVIDUAL WELLS.

At Godfrey, in the northwest part of the county, a deep well has recently been sunk to the St. Peter sandstone and this supplies the Monticello Seminary. Wells at the railway station reach a depth of about 30 feet without entering rock.

At Alton the public water supply is pumped from the Mississippi River. Wells on the uplands in the north part of the city penetrate 30 to 40 feet of drift, and frequently obtain water without entering the rock.

At Upper Alton the wells on the upland are usually obtained at 30 to 40 feet, near the base of the drift. The loess in this village has a thickness of 20 feet or more, but is underlain by typical till, exposures of which may be seen near Wyman Institute. The village contemplates putting in waterworks, which will be supplied from wells in the Mississippi Valley.

In the vicinity of Fosterburg, in the northern part of the county, wells are obtained at about 25 feet. The loess in that locality is only about 8 feet in depth.

At Edwardsville the wells range in depth from 20 to 80 feet, the shallower ones being obtained just below the loess, while the deeper ones pass through a large amount of till and enter rock near the bottom. This city is also contemplating waterworks, but the source of supply has not been ascertained.

At Collinsville the public water supply is from two wells 575 and 600 feet in depth. The wells are located on the Mississippi River bluff, 100 feet above the railway station, and water will rise to a level 120 feet below the surface. The wells have a combined capacity of not more than 50,000 gallons per day. The water is slightly saline, but can be drank by most people without discomfort. The supply is probably either from the Coal Measures or Lower Carboniferous sandstone. The drift and loess at these wells is about 90 feet in depth, but probably not less than 40 feet is loess. Attention is here called to an error in the altitude of the well mouth given in the writer's paper in the Seventeenth Annual Report (p. 811), the altitude being 565 feet instead of 465 feet as there given.

In the vicinity of Troy wells are obtained at about 30 feet. The loess at this village is 12 or 15 feet in depth.

In the vicinity of St. Jacobs wells occasionally enter rock at depths of 40 or 50 feet if on low ground between the drift ridges. The drift is probably much thicker on the drift ridges, though no records of deep wells were obtained.

At Highland the wells on low ground among the drift ridges enter rock at 25 to 50 feet, but many are obtained without reaching the rock. North and east of Highland wells usually obtain water at about 20 feet without entering rock.

At Grant Fork rock occurs at a level only 20 feet below the upland plain, and several wells west of this village have been drilled into the rock a few feet. No data were obtained concerning the depth of wells in the northeast fourth of the county.

BOND COUNTY.

GENERAL STATEMENT.

Bond County is situated east of Madison, in the south-central part of the State, and has an area of 380 square miles, with Greenville as its county seat. The greater part of the county is drained southward through Shoal Creek, a tributary to Kaskaskia River. The Kaskaskia touches the southeast corner of the county. The streams afford rather imperfect drainage, and the white clay which covers the glacial drift is a slow absorbent of rainfall. The excess of rainfall is therefore largely disposed of by evaporation except on the immediate border of drainage lines.

A system of drift ridges leads across the county from northeast to southwest. There are also scattering knolls over all of the county. These knolls and ridges rise in some cases 50 or even 75 feet above the bordering plains.

The thickness of the drift is known at but few points. Six borings which have reached rock show an average thickness of 85 feet, which is probably not far from the average for the county. The upper 20 feet consist of yellow or ash-colored clays, which in places assume a sandy structure and supply water for the majority of wells. The deeper portion of the drift consists usually of blue till, but a boring at Greenville shows a large amount of sand and gravel.

INDIVIDUAL WELLS.

Wells in the vicinity of Sorento, in the northwest part of the county, often reach a depth of 30 feet and penetrate the following beds:

Generalized section of wells in northwestern Bond County, Illinois.

	Feet.
White clay	5
Yellow till	12–15
Blue till	10–15

Near Old Ripley the drift is about 50 feet in depth, but only a few wells reach the rock. Its structure is like that at Sorento.

At Greenville wells are usually obtained at 35 feet in sand and gravel below clay. The public water supply is from a well 22 by 35 feet, in the bottom of which several tubular wells have been sunk to depths of 10 or 20 feet. There are also two 6-inch wells sunk near the large well, which reach a depth of 45 feet. A coal boring at Greenville, reported in the Geology of Illinois, penetrated 204 feet of drift, as follows:

Section of coal boring at Greenville, Illinois.

	Feet.
Soil and clay	10
Sand and clay	20
Coarse sand	10
Gravel	20
Cemented gravel (possibly till)	90
Clay and sand	20
Sand	8
Light clay and sand	8
Dark clay and sand	18
Total drift	204

A well in the valley of Shoal Creek, 3 miles above Greenville, is reported to have reached rock at 87 feet and to have been sunk entirely through blue clay. Wells on a drift ridge in the city of Greenville in some cases reach a depth of 80 or 90 feet, in which the upper 20 feet is largely clay and the remainder sand and gravel.

At Smithboro a coal boring reported in the Geology of Illinois penetrated 95 feet of drift, as follows:

Section of coal boring at Smithboro, Illinois.

	Feet.
Soil and clay	15
Hardpan (probably till)	60
Blue clay	10
Hardpan	10
Total drift	95

In the vicinity of Woburn wells on low drift ridges reach a depth of 40 feet and are largely through gravel. On the plain east of Woburn wells are usually obtained at about 25 feet and are mainly through till.

In the east part of the county, near Pleasant Mound, wells are usually obtained at 25 or 30 feet without entering rock. A well on a knoll 1½ miles southeast from Pleasant Mound entered rock at 48 feet, which is about the level of the base of the knoll.

FAYETTE COUNTY.

GENERAL STATEMENT.

Fayette County is situated in the south-central part of the State, and has an area of 720 square miles. Vandalia is the county seat. The Kaskaskia River leads nearly centrally from northeast to southwest through the county and has broad bottoms averaging probably 3 or 4 miles in width. No large tributaries enter within the limits of this county. Like Bond County a portion of Fayette has imperfect drainage, due in part to the poor development of drainage lines and in part to the compact white clay which caps the surface.

A system of prominent drift ridges is found in the southwestern part of the county. The most prominent belt leads from Vera past Vandalia to Pleasant Mound in Bond County. It stands in some places 100 feet above the bordering plains and presents a complex series of ridges and knolls with an average breadth of 2 miles. The remainder of the county has a nearly plane surface.

No records of wells have been obtained by the writer in this county except at Vandalia, and the thickness of the drift is known at but few places, where outcrops of rock occur. There is apparently a filling of about 100 feet along the Kaskaskia River and its preglacial tributaries, but on the uplands the thickness is only 20 to 40 feet.

INDIVIDUAL WELLS.

Wells on the drift ridges in the vicinity of Vandalia frequently reach a depth of 75 feet and are mainly through a gravelly drift. The Manual of American Waterworks (1897) reports that a waterworks system is about to be constructed which will obtain its supply from the Kaskaskia River.

A boring for coal made at this city reached a depth of 574 feet. It entered rock at about 95 feet, after penetrating a complex series of drift beds.

From the report in the Geology of Illinois (Vol. VI) the following information concerning wells is obtained. In the north part of the county the wells are 12 to 18 feet, with weak veins of water. A well near Ramsey was dug 100 feet through clay and gravel to solid rock. Wells about a mile south of Vandalia are reported to reach a depth of 60 or 65 feet on the drift ridges and about 30 feet on the bordering plane tracts. The wells usually pass through a small amount of clay at the top, beneath which they are largely through sand.

EFFINGHAM COUNTY.

GENERAL STATEMENT.

Effingham County is situated in the south-central part of the State, immediately east of Fayette County, with Effingham as the county seat, and has an area of 490 square miles. The greater part of the county is tributary to Little Wabash River, which has a southward course through its central portion. From the western border of the county the drainage is westward to the Kaskaskia. The divides in this county are poorly drained as in neighboring counties, and there is a coating of white clay over the entire upland surface which absorbs water very slowly.

The drift surface is generally plane, there being no prominent ridges or knolls, such as occur in the neighboring counties on the north and west. Rock is exposed along the Little Wabash and its tributaries and also along tributaries of the Kaskaskia at levels only 20 to 40 feet below the bordering uplands. The thickest section of drift obtained within the county is only 60 feet. The upper part of the drift to a depth of 25 feet or more is composed of clays of yellow or brown color which usually afford water for the wells. Under these clays is a hard blue till extending frequently to the rock.

INDIVIDUAL WELLS.

At Altamont a well at the Boyer House penetrated about 15 feet of white and yellow clays with few pebbles, beneath which a hard brown till was entered, and below that, at a depth of a few feet, a blue till. The well terminated in this blue till at a depth of 47 feet. Other wells in the village obtain water without entering the blue till. Within a few miles southwest

of Altamont, on the divide between the Little Wabash and Kaskaskia, wells enter rock at about 30 feet and obtain water at 40 or 50 feet.

In the vicinity of Moccasin and Beecher wells occasionally enter rock at 30 to 40 feet, but are usually obtained at 20 or 30 feet from drift beds of sandy structure.

In the vicinity of Effingham wells are obtained at 18 to 20 feet in sandy beds below till. Rock is entered at 25 or 30 feet. The supply for waterworks is pumped from Little Wabash River.

In the vicinity of Edgewood and Mason, in the southern part of the county, rock is usually entered at 20 to 25 feet, but most of the wells obtain their supply from near the base of the drift. A coal boring near Edgewood is reported, in the Geology of Illinois, to have penetrated 59 feet of drift.

JASPER COUNTY.

GENERAL STATEMENT.

Jasper County is situated east of Effingham, with Newton as the county seat, and has an area of 506 square miles. The Embarras River runs southeastward through the central portion of the county. Its tributaries are mainly on the northeast, leaving the western and southern portions of the county outside its drainage basin and tributary to the Little Wabash. The valley of the Embarras is nearly 2 miles in average width and has sandy bottoms. The uplands in this county, as in the neighboring counties on the north and west, are covered with a white clay, which absorbs rainfall very slowly.

The drift, like that of Effingham County, is composed mainly of till of moderate depth, seldom more than 50 feet. Along the Embarras River, however, the depth is greater and may exceed 100 feet. Tributaries of the preglacial Embarras have been filled so completely that their courses can scarcely be traced. The wells are usually obtained at depths of only 20 or 30 feet. But few records have been procured, the conditions for wells being somewhat uniform throughout the county.

INDIVIDUAL WELLS.

In the vicinity of Newton wells are usually about 20 feet deep, and in a few instances they reach rock at that depth. The waterworks supply is pumped from the Embarras River.

At St. Marie a well at Mr. Picquet's did not enter rock at a depth of 30 feet, but other wells in the village strike rock at only 16 feet. West from St. Marie, along the divide between Embarras and Little Wabash rivers, wells are about 20 feet in depth and do not enter rock.

Wells along the Embarras River in the southeast part of the county are 30 to 45 feet in depth without entering rock. After penetrating a few feet of sand they are largely through blue till.

CRAWFORD COUNTY.

GENERAL STATEMENT.

Crawford County is situated on the eastern border of the State immediately south of Clark County and east of Jasper. It has an area of 452 square miles, with Robinson as the county seat. The eastern border is followed by the Wabash River, which receives the drainage of a narrow strip along its west bluff. The western half of the county is tributary to the Embarras River, but that stream touches only the extreme southwest corner of the county. This county, like those on the north and west, is covered with white clay which absorbs rainfall slowly, although not so impervious to water as the white clay in the south-central part of the State.

The drift is apparently of slight depth on the uplands, rock being entered in wells at many points within 10 or 15 feet of the surface. There may, however, be deeply filled preglacial valleys tributary to the Wabash and Embarras, whose courses are concealed by the drift. Where wells do not enter rock they usually obtain water at a depth of 20 feet or less, and thus do not test the thickness of the drift in its deeper portions. Wells which enter rock obtain water without penetrating to great depth, there being few wells more than 100 feet in depth.

INDIVIDUAL WELLS.

In the northern part of the county wells are usually obtained in sandstone at a depth of 35 feet or less. The drift is often not more than 15 feet in depth.

In the vicinity of Trimble the rock is in places scarcely 10 feet below the surface and wells are obtained at moderate depths in sandstone.

At Robinson wells are 20 to 25 feet in depth and usually enter sandstone a few feet. The mayor, Mr. Aldridge Walters, estimates that good wells will yield 40 or 50 barrels per day.

In the vicinity of Duncanville wells are obtained in sand below clay at a depth of 18 or 20 feet. On the higher parts of the upland rock is entered at 10 or 15 feet. In the vicinity of Flat Rock, also, the drift is but 10 or 15 feet in depth.

In the west part of the county, in the vicinity of Oblong, wells are usually obtained at about 16 feet without entering rock.

LAWRENCE COUNTY.

GENERAL STATEMENT.

Lawrence County is situated south of Crawford, on the east border of the State, and has an area of 360 square miles, with Lawrenceville as the county seat. The Wabash River forms the eastern border of the county and Embarras River traverses it nearly centrally. Both streams have broad sandy bottoms several miles in width. The lowlands connected with these bottoms are poorly drained, but uplands are hilly and well drained. The higher portions of the county have a capping of white clay, but the lowlands and river bottoms are usually covered with sand.

The drift on the uplands is very thin, rock usually being found within 10 or 15 feet of the surface. Wells are, however, obtained at moderate depths, there being few which have failed to obtain water within 50 feet of the surface. On the lowlands the drift is probably thick, though wells are obtained without reaching the underlying rock. A well across the Wabash, at Vincennes, Indiana, reached a level about 60 feet below the river before entering rock.

INDIVIDUAL WELLS.

At Lawrenceville the best wells are obtained from sandstone at a depth of about 60 feet. Rock is entered at only 10 to 15 feet.

In the vicinity of Sumner strong wells are obtained at about 20 feet from sand and gravel below clay.

At St. Francisville the wells average only 15 feet in depth, mainly through sand.

RICHLAND COUNTY.

GENERAL STATEMENT.

Richland County is situated immediately west of Lawrence, with Olney as the county seat, and has an area of 361 square miles. The eastern portion of the county drains southward to Bonpas River and the western

through Fox River, a tributary to the Little Wabash. This county, like those to the north and west, has a coating of white clay which is very slowly pervious to water. The excess of rainfall escapes largely through evaporation. Along the streams and in lowlands there is usually a black mucky soil, much richer than the white clay of the uplands and more readily pervious to water.

On the uplands the drift is generally very thin, the rock often being entered at only 10 or 15 feet. On the lowlands the thickness is much greater, and wells are obtained at 20 feet or less without entering the rock.

INDIVIDUAL WELLS.

At the city of Olney private wells usually obtain water at a depth of 10 or 12 feet from a gravelly bed resting on the rock. The waterworks supply, which is chiefly for fire protection and lawns, is pumped from Fox River. A boring 2,000 feet in depth was made at this city for the purpose of obtaining an artesian well. A salt water was struck which does not overflow, and no use is made of the well. South of Olney, near Parkersburg, a well is reported to have struck wood in clay at 20 feet.

In the north part of the county, near Dundas, rock is usually entered at 12 to 18 feet, though wells are sometimes of less depth.

CLAY COUNTY.

GENERAL STATEMENT.

Clay County is situated west of Richland and south of Effingham County. It has an area of 470 square miles, with Louisville as the county seat. The county is traversed by the Little Wabash River nearly centrally in a northwest to southeast course. The greater portion is directly tributary to this stream, but a narrow strip on the western border is tributary to Skillett Fork, a stream which enters the Little Wabash near its mouth. This county, like the neighboring counties just discussed, has a coating of white clay several feet in depth, which is very slowly pervious to water. The streams, however, are bordered by broad bottoms with looser and more fertile soil.

The drift on the uplands is usually but 15 to 30 feet in depth. Wells are in many cases obtained in the drift, but a large number penetrate the underlying rock a few feet. The drift along the streams is probably of

greater depth than on the uplands, but no well records have been obtained to demonstrate this greater thickness.

INDIVIDUAL WELLS.

In the vicinity of Iola, in the northwest part of the county, wells obtain water at 12 to 15 feet without entering rock. They are mainly through a yellow clay.

At Louisville rock is entered at about 27 feet, but wells frequently obtain water in the lower part of the drift. An exposure on the bluff of Little Wabash River in this village shows the following beds:

Section of bluff of Little Wabash River near Louisville, Illinois.

	Feet.
Brown silt with few pebbles	6
Brown sandy gravel	5
Brown leached till	4
Gray calcareous till	12
Coal Measures shale	10
Total drift	27

On the uplands west and south from Louisville rock is usually entered at 15 to 20 feet, though at elevations a few feet higher than the site of the village.

At Flora rock is usually struck at 15 or 20 feet and wells are obtained at 30 to 50 feet.

In the vicinity of Xenia rock is entered at about 15 feet and wells obtain water at slight depth in the underlying sandstone or sandy shale.

MARION COUNTY.

GENERAL STATEMENT.

Marion County is situated west of Clay County and south of Fayette, about midway between the Wabash and Mississippi rivers. It has an area of 580 square miles, with Salem as the county seat. The divide between the Mississippi and Wabash rivers passes through the eastern part of the county. The greater part of the county drains westward through small creeks into the Kaskaskia. The eastern part drains southward through Skillett Fork, a tributary of Little Wabash River. The streams afford imperfect drainage, and the sheet of white clay that covers the county absorbs rainfall very slowly. The excess of rainfall is therefore disposed of by evaporation.

Throughout much of the county rock is entered in wells and coal shafts at depths of only 20 or 30 feet, but borings at Salem, Odin, and Sandoval penetrate over 100 feet of drift, apparently striking the line of a preglacial valley. Where the drift exceeds 20 feet in depth its lower portion is usually a blue till, but where less than 20 feet the till is of a yellow or brown color. Wells are usually obtained at only 15 to 30 feet, and the majority do not enter rock.

INDIVIDUAL WELLS.

At Patoka, in the northwest part of the county, a well at the railway station is reported in the Geology of Illinois to have struck rock at a depth of 60 feet. It penetrated the following beds:

Section of well at Patoka, Illinois.

	Feet.
Soil, clay, etc	15
Hardpan	15
Blue pebbly clay with fragments of coal and wood	30
Fossiliferous limestone	2
Soft shale	30
Total depth	92

The wells in that vicinity ordinarily obtain water without entering rock.

At Kinmundy, in the north part of the county, rock is entered at 12 to 20 feet, and wells often penetrate it a few feet to obtain water.

At Salem wells are usually obtained at about 20 feet from sandy beds in the drift. A coal boring reported in the Geology of Illinois penetrated 126 feet of drift, as follows:

Section of coal boring at Salem, Illinois.

	Feet.
Soil	2
Ferruginous crust of clay	3
Yellow till	9
Yellow till and sand	10
Blue till	50
Brown clay, containing wood	30
Blue clay, sand, and wood	12
Black soil	1
Blue mud and sand	9
Total drift	126

At Odin a coal boring penetrated 100 feet of drift, and at Sandoval 128 feet. Wells at Sandoval obtain water at 14 to 18 feet from a sandy clay. A good well is estimated to yield 35 barrels a day.

At Centralia wells obtain water at 14 to 30 feet from clay or gravel. The public supply is from impounded water.

CLINTON COUNTY.

GENERAL STATEMENT.

Clinton County is situated west of Marion County, in the southwestern part of the State, with Carlyle as the county seat, and has an area of 494 square miles. The Kaskaskia River leads southward through the eastern part of the county and there turns westward, forming the south boundary. Shoal Creek, its largest tributary, traverses the west-central part of the county and enters the Kaskaskia about 8 miles from the west border of the county. Crooked Creek, an eastern tributary, forms a part of the south boundary of the county. The streams have channels sunk but a few feet below the level of the bordering plains and drainage lines are not well developed. The compact white clay which covers the county absorbs the rainfall slowly, thus leaving much of it to be disposed of by evaporation.

Occasional drift ridges and knolls break the monotony of the plain. The highest reach elevations of 50 to 75 feet or more above the plain, and the majority have a height of fully 30 feet. The best developed system of ridges appears along the Kaskaskia River, east and southeast of Carlyle. There is a nearly continuous chain of knolls about 5 miles in length, which crosses the Baltimore and Ohio Railway in north to south direction about 3 miles east of Carlyle. These knolls and ridges connect on the north with those in Bond and Fayette counties already discussed.

The thickness of the drift in this county seldom exceeds 50 feet, and not a few wells enter rock at 15 to 30 feet. A few drift sections are reported in the Geology of Illinois which penetrate 70 feet of drift. In its thicker portions the drift includes a hard blue till near its base, but it usually has a yellow color to a depth of at least 20 feet. The wells are obtained either in the sandy portions of the yellow till or at slight depth in the underlying rock. The blue till is apparently very compact and a poor medium for supplying water.

INDIVIDUAL WELLS.

At Carlyle wells are usually obtained at about 25 feet without entering rock. The waterworks are supplied from the Kaskaskia River.

A well on one of the drift knolls southeast from Carlyle in sec. 14, T. 1 N., R. 2 W., was mainly through sand and gravel to a depth of 46 feet. It is thought by the residents that most of these knolls and ridges contain much sand and gravel.

The following table of well borings is compiled from data furnished in the Geology of Illinois (Vol. III):

Wells in Clinton County.

Owner or location.	Altitude (above tide).	Depth.	Remarks.
	Feet.	*Feet.*	
Sec. 5, T. 3, R. 2 W	500	40	Rock at bottom.
Sec. 6, T. 3, R. 2 W	500	36	Rock at bottom.
Beaver Prairie, T. 3, R. 3 W	475	50	No rock; several wells.
Drift knolls, T. 1, R. 3 W	475	70	Several wells; drift about 70 feet.
Sec. 34, T. 2, R. 4 W	475	70	On knoll, mainly sand.
Mr. Marks, at Breese	450	52	Rock at 16 feet.
Trenton, coal shaft	490	27	Rock entered at 27 feet.

ST. CLAIR COUNTY.

GENERAL STATEMENT.

St. Clair County is situated in the southwestern part of the State and borders the Mississippi River for a few miles opposite the city of St. Louis. It has an area of 680 square miles, with Belleville as the county seat. The Kaskaskia River crosses its southeastern corner, and the greater part of the county is tributary to that river through Silver and Richland creeks, there being only a narrow strip along the bottoms and east bluff of the Mississippi which is not tributary to it. This strip along the Mississippi bluffs is largely underlain by St. Louis limestone, in which subterranean drainage is developed through caverns and sink holes. The western portion of the county is covered with a deposit of porous loess, which extends as far east as the meridian of Belleville. The eastern portion is largely covered by a white clay, though scarcely so compact as that found in counties to the east.

A belt of prominent drift ridges leads southward through the eastern half of the county, passing between Lebanon and O'Fallon, and just east of the city of Belleville. These ridges rise in places to a height of fully

100 feet above the bordering plain, and are a continuation of the belt which crosses southeastern Madison County, noted above. East of this belt there are a few isolated knolls or groups of knolls which stand 30 to 50 feet or more above the border plains.

In the elevated limestone district on the west border of the county there is but little glacial drift beneath the loess, but eastward from the belt of drift ridges just noted the county is coated so heavily that wells seldom reach the rock. The extreme southeast part of the county, however, has a thin coating of drift, and wells often enter the rock. The drift ridges are composed in part of till and in part of sand and gravel. A blue till is found near the base, but the upper 30 or 40 feet is usually of brown or yellow color.

INDIVIDUAL WELLS.

At East St. Louis, in the extreme northwest corner of the county, on the low bottom of the Mississippi River, borings and bridge foundations have penetrated 120 to 140 feet of fine sand, reaching a level about 100 feet below the low-water mark of the river before entering rock. Private wells are obtained at a depth of about 35 feet. The public water supply is pumped from the Mississippi River.

At East Carondelet, also in the Mississippi bottoms, about 6 miles below East St. Louis, wells are usually obtained at a depth of about 40 feet, but Mr. H. L. Pugh has driven several wells to a depth of 60 feet. The upper 40 feet is a fine sand, but the lower 20 feet is a fine gravel or coarse sand. Piles driven at the foundation of the Meier Iron Works are thought to have struck solid rock at a depth of 90 feet, or a level nearly 60 feet below the low-water mark of the river.

On the Mississippi bluff in the northwest part of the county the loess ranges in thickness from 20 to about 50 feet, and the few wells which are made in that region are usually sunk some distance into the underlying rock. The residents usually depend upon cistern water.

At Millstadt the best wells are obtained in rock at a depth of 25 to 40 feet. A test boring made at this village reached a depth of 620 feet. The water has a head 75 feet below the surface and there is only a small amount, estimated at about 4 gallons per minute.

At Belleville the waterworks is supplied in part from a well drilled in the valley of Richland Creek and in part by impounded water from Richland Creek and a tributary. The well entered rock at a depth of 42 feet after penetrating the following series of drift beds:

Section of well at Belleville, Illinois.

	Feet.
Yellow till	25
Black muck, resembling soil	2
Yellow clay	6
Blue clay	9
Total drift	42

Several prospect borings for the waterworks have been made along Richland Creek Valley, between Belleville and O'Fallon, which penetrate in some instances 80 feet of drift, mainly till. The amount of water is scarcely sufficient to furnish a supply for water works, hence the use of impounded water is continued. A well at the Star Brewery, in the northern part of Belleville, reached a depth of 503 feet and obtained a slightly saline water, with head 80 feet below the surface. The depth of the drift is 87 feet. Coal shafts near the Louisville and Nashville depot, in the northern part of Belleville, penetrate mainly blue till and enter rock at depths of 40 to 80 feet, the rock surface being somewhat uneven. A coal shaft just south of Belleville enters rock at 30 feet, and there are exposures of rock within the city limits.

At the village of Lebanon, in the northeast part of the county, shallow wells obtain water from gravel below clay at a depth of 30 or 40 feet. Considerable wood is found in some of the wells. There are also several deep wells in the village obtaining water from limestone at 150 to 200 feet. On a drift ridge 2 miles north of the village a well made by D. Bitzer reached a depth of 86 feet without encountering rock. The lower 46 feet was a hard blue till containing fragments of wood. The upper 40 feet consisted of alternations of clay with gravel. The altitude at this well is fully 60 feet above the railway station at Lebanon.

At Summerfield rock is entered at about 35 feet, but on the plain north of this village the wells usually penetrate 50 feet of drift before entering rock.

A coal shaft at Mascoutah is reported in the Geology of Illinois to penetrate the following beds of drift:

Section of coal shaft at Mascoutah, Illinois.

	Feet.
Soil and clay	20
Sand	6
Blue, gray, and red clay	50
Coarse sand with wood	6
Total drift	82

At Rentchler wells enter rock at about 40 feet, but on the drift ridges between that place and Wilderman two wells are reported to have reached a depth of 85 feet without entering rock.

The following section of thick drift is reported in the Geology of Illinois. The boring was made in sec. 20, T. 1 S., R. 6 W.:

Section of a boring in sec. 20, T. 1 S., R. 6 W.

	Feet.
Soil and yellow clay	14
Reddish brown gravel and sand	28
Blue clay	83
Total drift	125

In the vicinity of Freeburg and Smithton rock is entered in the deeper wells at about 25 to 30 feet. The upper 5 or 10 feet is a loess or pebbleless silt, and the remainder is a brown clay containing few pebbles. There appears to be but little typical till in this locality or, for that matter, in any part of the county west and south from Belleville.

At Lementon a coal boring reported in the Geology of Illinois has the following section of drift:

Section of drift beds in a coal boring at Lementon, Illinois.

	Feet.
Soil	3
Yellow clay	14
Sand and gravel	1
Blue clay	20
Clay resembling soil	1
Blue and yellow clay	11
Red and yellow sand	1
Total drift	51

On a drift ridge southwest of Lementon a well made by Mr. L. Hermann reached a depth of 65 feet without entering rock. The upper 23 feet was mainly till; the remainder sand and gravel.

Near New Athens coal shafts and borings enter rock at depths ranging from 37 to 75 feet. A well at J. Hardy's, south of New Athens, reached a depth of 90 feet without entering rock, and several wells in that vicinity are 50 feet in depth. Southeast from New Athens rock is usually entered within 30 feet of the surface. Some of the highest points have rock at surface.

MONROE COUNTY.

GENERAL STATEMENT.

Monroe County borders the Mississippi River below St. Clair County, and has an area of 380 square miles, with Waterloo as the county seat. The western part of the county is largely occupied by the St. Louis limestone, and is characterized by subterranean drainage through sink holes and caverns. The limestone is covered with a deposit of loess, but there is very little glacial drift. In the northern end of the county, near Columbia, there is a lowland occupied by Coal Measures, in which drift 40 feet or more in depth has been deposited. The eastern part of the county is occupied by Coal Measures and its drainage is tributary to the Kaskaskia, that stream being the eastern border of the county.

The belt of drift ridges which have been traced southward through St. Clair County cross the eastern border of Monroe County, following nearly the west bluff of the Kaskaskia River. The drift on this ridged belt has been penetrated in one instance 115 feet and in several instances 60 to 75 feet without reaching the rock. It is found to be partly sand and partly till. West from this ridged belt the drift is thin, seldom exceeding 20 feet. Wells are usually obtained from the rock, except along the belt of ridged drift and in the Mississippi bottoms. Strong wells are seldom obtained in the rock at less than 50 feet, and not infrequently they are 80 feet in depth. The wells in the Mississippi Valley are only 40 or 50 feet in depth, and are largely through fine sand. The wells along the belt of ridged drift vary greatly in depth, some being obtained at about 30 feet, while others are sunk to twice or thrice that depth.

INDIVIDUAL WELLS.

At Columbia the wells are 20 to 45 feet in depth, the deeper ones being from the rock. A prospect boring for artesian water was sunk to a depth of 1,010 feet. It has a head 10 or 15 feet below the surface. No use is

made of the well at present. Exposures in the ravines near Columbia show a deposit of loess about 12 feet in depth, beneath which there are yellow and blue clays containing a few pebbles and an occasional bowlder as well as numerous fragments of wood. The rock fragments are far less numerous than in typical till.

At Waterloo the wells range in depth from 20 to 80 feet, and nearly all are from limestone. One at the mill, however, 20 feet in depth, was obtained without entering rock. A well at the electric light plant is reported to have entered rock at about 30 feet. The Manual of American Waterworks (1897) reports that an impounding reservoir has been constructed with a view to obtaining a public water supply.

In the vicinity of Burksville wells occasionally reach a depth of 30 or 40 feet before entering rock. They are mainly through a nearly pebbleless clay, yellow at top and blue in its deeper portion.

In the vicinity of Glasgow (Renault post-office) wells are often sunk to a depth of 50 feet. The distance to rock ranges from 10 feet to fully 50 feet, but a large amount of the clay above the rock is apparently residuary, there being very little glacial drift in this locality. The clay has the deep reddish brown color characteristic of clay formed from the St. Louis limestone. About 3 miles east of Glasgow, on a plain perhaps 75 feet lower than the village, the drift consists of a clay with few pebbles and occasional bowlders, similar to the deposits at Columbia noted above. The depth to rock is about 20 feet.

The following records of deep wells are from the drift ridges in the eastern part of the county:

At W. M. Bartol's, 2 miles east of Hecker post-office, a well 60 feet in depth is through till in the upper half and sand in the lower. A well at a schoolhouse in sec. 11, T. 3 S., R. 8 W., 60 feet in depth, was mainly through till, and one at a farmhouse a half mile farther south, 75 feet in depth, is also largely till, with wood at 72 feet. A well made by F. Voss, in sec. 36 of this township, reached a depth of 115 feet, and is mainly through sand.

In the vicinity of Hecker, on the plain west of this ridge and about 30 feet lower elevation, wells enter rock at only 20 feet. They penetrate a brown clay containing a few small pebbles. Water is usually obtained at about 30 feet.

RANDOLPH COUNTY.

GENERAL STATEMENT.

Randolph County is situated on the east border of the Mississippi River, immediately below Monroe County, and has an area of 560 square miles, with Chester as the county seat. The Kaskaskia River leads southward through its western portion and drains the western half of the county. The eastern part of the county is tributary to Marys River, which enters the Mississippi just below Chester.

The portion of the county on the immediate border of the Mississippi Valley stands higher than the more remote portions of the county, there being a gradual descent from the Chester to the Coal Measures formations, notwithstanding the fact that the former passes beneath the latter. The elevated tracts near the Mississippi are capped with a porous loess, but the lower tracts to the north have a silt nearly as compact as the white clay into which it graduates toward the north. The belt of ridged drift which has been traced southward through St. Clair and eastern Monroe counties crosses the Kaskaskia in northern Randolph County and passes southeastward through the central portion of the county just south of the villages of Sparta and Steeleville. The belt in this county has a width of scarcely a mile and has less relief than in the districts farther north, its crest being seldom more than 50 feet, and usually but 25 or 30 feet above the border tracts.

On the elevated portion of the county outside the drift ridge just mentioned there is less drift than in the lower districts to the north, and typical till is seldom found. The valleys are filled with a clayey deposit, in which there are a few pebbles and an occasional bowlder. The uplands have scarcely a trace of drift. Along the belt of ridged drift and in the district to the north typical till is quite prevalent. The thickness of drift in the northern portion of the county varies greatly because of inequalities of the underlying rock. Within the limits of the village of Sparta the thickness varies fully 100 feet. Wells frequently obtain water without entering rock at depths of 15 to 30 feet. In the elevated portion of the county the residents depend largely upon cistern water, though it appears that wells may be obtained at depths of only 50 to 75 feet.

INDIVIDUAL WELLS.

At Red Bud, in the northwest corner of the county, wells usually obtain water at about 40 feet, and rock is entered at 12 to 20 feet. Three deep wells have been sunk at this village, one being 1,350 feet, another 580, and a third 300 feet in depth. The deepest well is sunk on ground standing about 450 feet above tide, and water rises only to a level 20 feet below the surface. The well 580 feet in depth is on ground 30 feet lower and has an overflow. The main supply of water appears to be from the Chester sandstone, which is struck in the deepest well at 230 to 290 feet, and in other wells at corresponding depths, allowing for difference in surface elevatioı

In the vicinity of Ruma wells obtain water from rock at about 30 feet, there being only 15 or 20 feet of loess and glacial drift.

Along the belt of ridged drift in the northwest part of the county the following sections of wells were obtained:

Well sections in drift in northwestern Randolph County, Illinois.

	Feet.
H. Mehring, sec. 6, T. 4 S., R. 7 W.; mainly till	60
H. Rabanack, sec. 6, T. 4 S., R. 7 W.; mainly sandy till	40
P. Ackermann, sec. 1, T. 4 S., R. 8 W.; blue till near bottom	30
John Hoy, sec. 12, T. 4 S., R. 8 W.; sand below till	45
F. Smith, 2 miles north of Wheaton; no rock, on drift ridge	100
C. Klepper, near Wheaton; no rock, on plain	65
H. Guebert, near Wheaton; wood and coal in blue till	47
F. Heitzemann, sec. 13, T. 4 S., R. 8 W.; blue till in lower part	50
G. Buck, sec. 19, T. 4 S., R. 7 W.; sand below till	30
F. Rehmer, sec. 19, T. 4 S., R. 7 W.; blue till at bottom	30
F. W. Rehmer, sec. 20, T. 4 S., R. 7 W.; entered blue till at 20 feet	65
D. Liddy, sec. 19, T. 4 S., R. 7 W.; mainly clay	60
E. Eggerding, sec. 20, T. 4 S., R. 7 W.; mainly blue clay	70
Mr. Minch, sec. 28, T. 4 S., R. 7 W.; rock at 23 feet	50
C. O'Hara, sec. 27, T. 4 S., R. 7 W.; mainly blue clay	75
S. H. Mann, sec. 34, T. 4 S., R. 7 W.; shale near bottom	60
J. Corsen, sec. 1, T. 5 S., R. 7 W.; bowlders near bottom	40
J. A. Mann, sec. 1, T. 5 S., R. 7 W.; no rock	46
Mr. Ore, sec. 5, T. 5 S., R. 6 W.; no rock	60
J. Steele, sec. 5, T. 5 S., R. 6 W.; no rock; blue till entered at 20 feet	75
J. Hare, sec. 4, T. 5 S., R. 6 W.; rock at 30 feet	60

At a creamery in Houston a well 50 feet in depth does not reach rock. It enters a blue clay containing wood at about 30 feet. A well near Houston, at W. McManis's, entered rock at about 57 feet. The lower 15 feet

was blue till. A well at J. Porch's, 35 feet in depth, is mainly through till, the lower part being of blue color.

A well on a knoll in sec. 10, T. 4 S., R. 6 W., obtains water in gravel at 25 feet. A well near the base of the knoll at 15 feet lower elevation enters rock at 20 feet.

At Coulterville wells enter shale at 20 to 25 feet and obtain water at about 30 feet. A boring 1,117 feet in depth obtained brackish water from the Chester sandstone, of which no use is made at present. A complete record of strata penetrated is published in the Final Report of Illinois Board of World's Fair Commissioners.

At Sparta the wells are seldom more than 30 feet in depth and obtain their supply from the drift. A boring 480 feet in depth made at this village furnishes water suitable for laundry purposes, but not for drinking. Several deep borings at this village obtain a supply of gas from the base of the Chester limestone at 840 to 864 feet. The drift at these borings ranges from 34 feet to 116 feet, the thickest being on the lowest ground (J. M. Nickles).

A coal shaft near Eden Station penetrated a complicated series of drift beds, a section of which appears on page 117

At Steeleville wells are usually obtained at 18 to 22 feet from sandy beds in the drift. An artesian well 312 feet in depth enters rock at 60 feet and furnishes water of good quality for drinking. The well overflows at the rate of about 2 gallons per minute. A complete section of the strata penetrated by this well is published by Professor Nickles in the report of the Illinois Board of World's Fair Commissioners.

Wells along the drift ridge both north and south from Steeleville have been sunk to depths of 40 or 50 feet without entering rock. They are mainly through till.

At Shiloh Hill, which stands on the outer border of the belt of ridged drift, wells have been sunk to a depth of 35 feet, in some cases penetrating wood near the bottom below till.

At Wine Hill, on a prominent point in the southern part of the county, a well is reported to have been sunk to a depth of 36 feet without entering rock, but rock is exposed in that vicinity at depths of 20 to 30 feet.

WASHINGTON COUNTY.

GENERAL STATEMENT.

Washington County is situated northeast of Randolph and east of St. Clair County, with Nashville as the county seat, and has an area of 540 square miles. The Kaskaskia River forms a portion of the north border and receives the drainage of the greater part of the county. The southeast part of the county drains southward through Beaucoup Creek, a tributary of the Big Muddy River. The uplands are coated with white clay scarcely as compact as that which is found in counties north and east.

The drift masks the preglacial ridges and hills without entirely concealing them. The drainage lines are probably in large part along preglacial courses, but at levels above the old rock floor. On the uplands or preglacial ridges the drift is only 10 or 20 feet in depth, but along the main preglacial valleys it probably exceeds 100 feet. Wells usually enter rock a few feet on the uplands, but on the lowlands and along valleys they obtain water from the drift. The depth rarely exceeds 40 feet.

INDIVIDUAL WELLS.

At Nashville the wells range in depth from 14 to 45 feet and usually enter rock a few feet. The strongest ones are estimated to have a capacity of 100 barrels a day, but many will yield not more than 10 barrels.

In the vicinity of Hoyleton the drift is 15 to 30 feet in depth and many wells are sunk into the underlying rock, obtaining water at about 40 feet. They are largely through till of brownish yellow color.

In the vicinity of Ashley wells range in depth from 8 feet to about 40 feet. Rock is entered at 15 or 20 feet, and the drift is mainly a brown till.

In the southern part of the county the distance to rock is usually but 12 to 20 feet and wells not infrequently penetrate it a few feet. A few knolls southwest of Oakdale appear to have no rock nucleus, but information concerning them is unsatisfactory.

In the northwest part of the county, on the borders of the Kaskaskia, wells are obtained without entering rock, at depths of 20 or 30 feet.

PERRY COUNTY.

GENERAL STATEMENT.

Perry County is situated south of Washington and east of Randolph County, with Pinckneyville as the county seat, and has an area of 440 square miles. The greater portion of the county is tributary to the Big Muddy River through Beaucoup Creek, which traverses the central part of the county in a north-to-south course. The Little Muddy forms the east border of the county south from the Jefferson County line. A few square miles in the west part of the county drain southwestward through Marys River to the Mississippi. The uplands are coated with compact white clay, but the valleys have a more porous deposit, forming a rich black soil.

The features of this county are very similar to those of Washington, the preglacial ridges being but partially concealed by the drift and having a coating only 10 to 20 feet thick on the highest portion, while the valleys are filled more deeply so that wells seldom enter the rock. Water is usually obtained at less than 40 feet, either from the drift or rock.

INDIVIDUAL WELLS.

The public water supply at Pinckneyville is obtained from an artesian well around the mouth of which a large well is excavated which receives the water. The well is reported by the Manual of American Waterworks to have a depth of 2,000 feet, and to be used principally for fire protection and street sprinkling. Private wells in that vicinity are obtained at about 30 feet. Rock is occasionally entered at less than 20 feet.

In the northwest part of the county, near Swanwick, wells usually obtain water at slight depth in the rock, the drift being often not more than 10 or 12 feet in depth.

In the southwest part of the county wells in several instances have encountered a blue mud carrying a large amount of wood. This apparently underlies the pebbly clays of the drift, but whether it in turn is underlaid by a till sheet is not ascertained.

In the vicinity of Duquoin wells range in depth from 15 to 40 feet, the usual depth being about 25 feet. They very seldom reach the rock. Coal shafts in that vicinity usually penetrate 30 to 45 feet of drift. The Manual of American Waterworks (1897) reports that waterworks are under construction.

In the spring of 1897 a boring was begun at St. Johns by the Illinois Central Coal and Salt Company which at last reports had reached a depth of more than 3,600 feet, and the drilling was still in progress. So far as the writer is aware, it is not exceeded in depth by any other boring in Illinois. The detailed record to a depth of 2,275 feet, which is given below, was furnished by John Forester, superintendent of the company, in July, 1898. Since then Mr. Forester has communicated the general results from time to time. A limestone formation forms the lower part of the section below the point where the detailed record ends. Mr. Forester states that a good quality of fresh water was found at a depth of 311 feet, but in such limited quantity that it was soon exhausted by a pump of 15-gallon per minute capacity. At 520 feet water was encountered which showed 15 per cent salt. Below this depth the salinity gradually increased until at 980 feet it reached 34 per cent. This water was cased out at 1,000 feet, and very little more was encountered until a depth of 1,604 feet was reached, when a vein of water with 38 per cent salt was struck. The well continued to yield this water until a bed of "fire clay" was reached at 1,949 feet. After passing through 20 feet of fire clay another yield of water with 38 per cent salt was found, which continued to a bed of shale at 2,026 feet. No more water was found until a depth of 2,271 feet was reached, when a vein of the same salinity was struck. At this depth there was apparently a crevice in the rock lined with crystals of calcite. As yet no identifications of the geological formations have been made. Temperature tests were made by Mr. Forester in March, 1899, when the boring had reached a depth of 3,600 feet. After an exposure of two hours the thermometer registered 93° F., and after an exposure of twenty-four hours 101° F.

Log of deep boring at St. Johns, Illinois.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Glacial drift	42	0- 42	Sandy shale	23	221- 244
Lime rock	3	42- 45	Fire clay and shale	12	244- 256
Sandy shale	16	45- 61	Shale with partings	55	256- 311
Shale and coal	10	61- 71	Sand rock, fresh water	178	311- 489
Sandy shale	25	71- 96	Lime rock	31	489- 520
Clay shale	30	96- 126	Sand rock, 15 per cent salt	15	520- 535
Sandy shale	80	126- 206	Sandy shale	28	535- 563
Sand rock	15	206- 221	Sand rock	15	563- 578

Log of deep boring at St. Johns, Illinois—Continued.

	Thickness.	Depth		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Sandy shale	32	578– 610	Shale	10	1,310–1,320
Lime rock	8	610– 618	Sand rock	10	1,320–1,330
Sand rock	25	618– 643	Shale	14	1,330–1,344
Shale	13	643– 656	Red marl	4	1,344–1,348
Sand rock	10	656– 666	Shale	4	1,348–1,352
Lime rock	3	666– 669	Lime rock	16	1,352–1,368
Sand rock	10	669– 679	Shale	7	1,368–1,375
Clay shale	30	679– 709	Sand rock	14	1,375–1,389
Sandy shale	35	709– 744	Lime rock	10	1,389–1,399
Mixed shale	35	744– 779	Sand rock	15	1,399–1,414
Lime rock	16	779– 795	Lime rock	6	1,414–1.420
Shale	20	795– 815	Shale with partings	20	1,420–1,440
Lime rock	25	815– 840	Lime rock	35	1,440–1,475
Clay shale	15	840– 855	Shale	23	1,475–1,498
Lime rock	5	855– 860	Sand rock	20	1,498–1,518
Sandy shale	15	860– 875	Shale, mixed	19	1,518–1,537
Clay shale	40	875– 915	Lime rock	4	1,537–1,541
Sandy shale	67	915– 982	Sandy shale	8	1,541–1,549
Lime rock	20	982–1,002	Lime rock	40	1,549–1,589
Sand rock	20	1,002–1,022	Shale	15	1,589–1,604
Lime rock	10	1,022–1,032	Lime rock, 38 per cent salt	92	1,604–1,696
Sandy shale	22	1,032–1,054	Shale	3	1,696–1,699
Sand rock	13	1,054–1,067	Lime rock, 38 per cent salt	250	1,699–1,949
Sandy shale	20	1,067–1,087	Fire clay or shale	20	1,949–1,969
Lime rock	20	1,087–1,107	Lime rock with partings	57	1,969–2,026
Red marl	4	1,107–1,111	Shale	10	2,026–2,036
Sand rock	39	1,111–1,150	Lime rock with partings	102	2,036–2,148
Sandy shale	40	1,150–1,190	Sandy lime rock	160	2,148–2,208
Sand rock	90	1,190–1,280	Light gray lime rock	63	2,208–2,271
Soft shale	10	1,280–1,290	Spar, calcite crystals	4	2,271–2,275
Sand rock	10	1,290–1,300	Light gray lime rock, hard	498	2,275–2,773
Blue lime	5	1,300–1,305	Light gray lime rock, soft	227	2,773–3,000
Sand rock	5	1,305–1,310	Mainly limestone to 3,600 feet	600	3,000–3,600

Altitude of well mouth, 463 feet above tide.

JEFFERSON COUNTY.

GENERAL STATEMENT.

Jefferson County is situated east of Washington and Perry counties, about midway between the Mississippi and Wabash rivers, with Mount Vernon as the county seat, and has an area of 580 square miles. The

drainage is mainly southward through the Big Muddy River. A small area in the northeast part is tributary to Skillett Fork, which flows southeast to the Little Wabash. The uplands are coated with white clay, which furnishes a slow absorbent for the rainfall. The portions of the county remote from the main drainage lines have imperfect drainage, the excess of rainfall being disposed of largely by evaporation.

The glacial deposits are generally thin and but partially conceal the preglacial ridges and valleys. They consist chiefly of a brownish yellow till. Throughout much of the county wells are reported to penetrate rock a few feet for the best supply, but weak wells are often supplied from the drift. No attempt was made to collect well records in the county.

The Manual of American Waterworks reports that at Mount Vernon the public water supply is from impounded water. The drift in the vicinity of that city is only 10 or 15 feet in depth.

WAYNE COUNTY.

GENERAL STATEMENT.

Wayne County is situated in the southeast part of the State, with Fairfield as the county seat, and has an area of 720 square miles. The Little Wabash River leads southward near the eastern border of the county and Skillett Fork leads southeastward through the southwestern portion. The uplands are covered with a silt deposit, but as they are more hilly than the counties to the north and west the water is drained to the lowlands readily, and a more compact deposit is found on the lowlands than on the hills or uplands.

The drift is generally a thin coating averaging scarcely 15 feet in depth on the higher parts of the county. In the lowlands and along valleys there is probably a greater depth. The thickness, however, has not been tested by well borings, the wells being obtained at comparatively slight depth from sandy beds in the drift. The drift consists usually of a brown till, which sets in below the white clay or surface silt at a depth of 6 or 8 feet.

INDIVIDUAL WELLS.

In the northwest part of the county, in the vicinity of Rinard, Blue Point, and Johnsonville, a large percentage of the wells enter rock at about 10 feet and obtain water at 30 to 40 feet or less.

In the vicinity of Cisne the drift has a thickness of 20 feet or more. Between Cisne and Fairfield, however, rock is often entered at 10 or 12 feet. The drift is also thin from Fairfield westward to Wayne City.

In the city of Fairfield the drift ranges in thickness from 8 to about 20 feet. Wells usually obtain water from rock at 25 feet or less. A few are drilled to a depth of 50 or even 70 feet.

East from Fairfield, in the vicinity of Meriam, wells enter rock at 10 feet or less. At Golden Gate Station, which stands on a low hill in the Little Wabash Valley, rock is struck at 16 to 20 feet.

EDWARDS AND WABASH COUNTIES.

GENERAL STATEMENT.

These two counties, with a combined area of but 440 square miles, are situated east of Wayne County and border the Wabash River. Albion is the county seat of Edwards, and Mount Carmel the county seat of Wabash County, The Bonpas River forms the dividing line between the counties and flows through a broad bottom deeply filled with drift or alluvium. This stream receives the drainage of much of both counties and carries it southward to the Wabash. The western portion of Edwards County drains into the Little Wabash River and the eastern portion of Wabash County into the main Wabash River.

Both counties are covered thinly with drift except in lowlands or valleys, and the preglacial ridges and hills stand 50 to 100 feet or more above the neighboring lowlands. There is a silt covering these hills and ridges, but it is more porous than the white clay. On the lowlands and flat areas within these counties the white clay appears in its compact phase. Wells are usually obtained on the lowlands at a depth of 20 feet or less without entering rock. On the uplands few wells are obtained without penetrating rock. The depth, however, is moderate, seldom exceeding 50 feet.

INDIVIDUAL WELLS.

Near Ellery, in western Edwards County, at the base of the east bluff of the Little Wabash, rock is usually entered at 10 to 20 feet, and wells obtain water at about 30 feet. On the bluff east of Ellery, at an altitude 60 feet above the station, wells enter rock at about 10 feet and obtain water at 40 or 50 feet.

At the village of Albion, which is situated on the divide between the Bonpas and Little Wabash, at an altitude about 150 feet above the streams, rock outcrops in numerous places, and the general thickness of the drift coating scarcely exceeds 5 feet. Wells are obtained at deuths of 40 or 50 feet, but the residents depend mainly upon cisterns.

In the valley of Bonpas River, near Brown Station, a well reached a depth of 61 feet without entering rock. It is reported to be mainly through sand with few if any pebbles.

At West Salem rock is usually entered in wells at 20 feet or less, and water is obtained at 30 or 40 feet.

At Mount Carmel the supply for the waterworks is obtained from a well in the Wabash Valley, which obtains water at the surface of the rock at a depth of 25 feet. Wells on the uplands in the city obtain water from the rock at depths of 25 to 40 feet, those on the lowlands near the Wabash obtain water from drift at a depth of 15 to 25 feet. West from Mount Carmel, in the vicinity of Maud and Belmont stations, wells in some cases obtain water in drift at 15 to 25 feet, but often enter the rock a few feet.

At Friendsville rock is struck at 12 to 15 feet and wells obtain water at about 30 feet. In a lowland tract 2 miles northeast of Friendsville, known as Crawfish Flats, wells 40 feet in depth do not reach rock, and logs are sometimes struck near the bottom.

WHITE COUNTY.

GENERAL STATEMENT.

White County is situated on the west border of the Wabash River, in the southeast part of the State, immediately below Edwards County, and has an area of 500 square miles, with Carmi as the county seat. The Little Wabash River traverses the county from north to south nearly centrally, and Skillett Fork, the main tributary of Little Wabash, leads southeastward across the northwestern part of the county and enters the Little Wabash just above the town of Carmi. In this county the streams are bordered by broad lowlands, filled apparently to considerable depth with glacial or alluvial deposits. The uplands are hilly and carry a very thin coating of drift, rock usually being entered within 10 feet of the surface. The entire county appears to have been covered by the ice sheet, for drift is found in the vicinity of the Wabash River both to the east and south of

the county limit in Posey County, Indiana, and Gallatin County, Illinois. The drift is mainly a brown till on which there is a coating of silt 6 or 8 feet in depth, which is probably the southward extension of the white clay, though a more porous deposit.

Wells are obtained on the uplands at moderate depths in the rock. On the lowlands they are shallow, seldom exceeding 30 feet, and obtain water from gravel or sand. Along the Wabash there is an extensive bottom underlain by fine gravel which affords water at about the level of the river.

INDIVIDUAL WELLS.

The public water supply at Carmi is pumped from the Little Wabash River. On the hills bordering the city wells enter rock at about 10 feet and water is obtained at 25 to 40 feet. These conditions prevail southwestward to the limits of the county.

In the south part of the county, in Heralds Prairie Township, there is considerable lowland, and wells occasionally reach a depth of 40 feet without entering rock; they are mainly through till.

In the Wabash bottoms, in the vicinity of Concord, (Emma post-office) the wells range in depth from 15 to 40 feet and are mainly through sand. About 3 miles east of this village wells obtain water in gravel at a depth of but 12 to 20 feet.

In the vicinity of Crossville and Phillipstown, northeast from Carmi, wells obtain water at about 25 feet in sand. A section near Phillipstown is noted in the Geology of Illinois, which exposes loess with fossils, 20 or 30 feet, beneath which is drift with pebbles and small granite bowlders, 35 feet.

At Grayville, in the northeast corner of the county, the loess has a thickness of 15 or more feet and is underlain by a thin sheet of till. Wells usually enter the rock, obtaining water at 30 to 40 feet. The waterworks obtains its supply from the Wabash River.[1]

HAMILTON COUNTY.

GENERAL STATEMENT.

Hamilton County is situated west of White County, in the southeastern portion of the State and has an area of 440 square miles, with McLeansboro as the county seat. Its southeast portion is drained by the north fork

[1] Manual of American Waterworks, 1897.

of Saline River and the northern portion is tributary to Skillett Fork of Little Wabash River. The lowlands are filled to considerable depth with drift, but the uplands, like those of White and the neighboring counties on the north and east, have a very thin drift coating, averaging scarcely 10 feet. The surface of the uplands is uneven, the preglacial ridges and hills being concealed but little by drift. A coating of silt covers the county, but it is much more porous than that of the more level counties on the northwest.

WELLS.

The wells of this county, as in neighboring counties, obtain water at depths of but 20 to 40 feet or even less, those on the uplands being generally into rock a few feet, while these on the lowlands are obtained without reaching the rock. No records of individual wells were collected.

The village of McLeansboro has a fire protection in cisterns distributed around the public square. There are also four tubular wells in the village, which, the mayor reports, have hard water, unfit for domestic use. The greater part of the citizens depend upon cistern water.

FRANKLIN COUNTY.

GENERAL STATEMENT.

Franklin County is situated south of Jefferson, about midway between the Wabash and Mississippi rivers, with Benton as the county seat, and has an area of 430 square miles. It is drained southwestward by the Big Muddy River, which crosses the west-central portion of the county. Its topography and general characteristics are so similar to Hamilton County that further description is scarcely necessary.

The wells on the uplands usually enter rock at a slight depth and penetrate it a few feet. If a good quality of water is not obtained cistern water is substituted. In the flats of the Big Muddy Valley, in the southwest part of the county, wells may be obtained without entering the rock.

JACKSON COUNTY.

GENERAL STATEMENT.

Jackson County is situated on the east border of the Mississippi River below Randolph County, with Murphysboro as the county seat, and has an

area of 580 square miles. Big Muddy River traverses its southern portion and Beaucoup Creek divides the northern portion nearly centrally. This county, like Randolph, has an elevated limestone tract along the Mississippi bluffs, from which there is a descent northeastward to the plains underlain by the Coal Measures. The elevated portion of this county has such a broken surface that it is but sparsely settled. At the south it extends beyond the glacial boundary and preserves all the ruggedness of the preglacial topography. The western portion appears to have been covered by the ice sheet, but the drift only partially fills the preglacial valleys.

The belt of ridged drift which has been traced southeastward across Randolph County to the border of this county is represented by occasional low ridges and knolls along the north border of the elevated tract just discussed as far east as the plain bordering Beaucoup Creek. The best development is found 1 to 4 miles southeast of Ava, along the turnpike leading from Ava to Murphysboro. The belt has not been identified in the eastern portion of the county. Northeast from this ridged belt there is generally present a sheet of typical till 20 to 40 feet or more in depth, and a similar deposit is found in the lowlands of the northeastern part of the county. The wells often penetrate a bed of blue silt containing wood at depths of 30 feet or more, beneath the pebbly glacial clays. Several instances are noted in the Geology of Illinois, and other instances came to the writer's notice, but no exposures of the silt were found by the writer.

On the elevated and hilly portions of the county the residents depend largely upon cistern water, but a few wells have been obtained at moderate depth. In the lower portions of the county wells are obtained at 20 to 50 feet, often without entering rock. Those in the Mississippi Valley are 30 to 40 feet in depth and mainly through a fine sand.

INDIVIDUAL WELLS.

The wells at Campbell Hill, in the northwest part of the county, have in a few instances been sunk into rock, which is reached at a depth of about 40 feet. The majority, however, obtain water from the glacial drift. Records of wells near this village appear in the Geology of Illinois, in which a blue mud containing wood is struck below the glacial drift at depths of 30 to 35 feet.

At Ava a coal boring is thought to have struck rock at 57 feet, but the deepest wells at this village are about 60 feet and do not enter rock. They are mainly through a pebbly clay with which thin sand beds are associated. A well at D. R. Wills's, on the crest of the drift ridge, 3 miles southeast of Ava, reached a depth of 65 feet without entering rock. Its altitude is fully 300 feet above the Mississippi River. Within 2 miles east from this well rock is struck at only 15 to 25 feet, on ground fully as elevated as the drift ridge. Immediately outside the drift ridge there is scarcely any drift covering the rock.

At Murphysboro wells are usually obtained at 15 to 30 feet from sand below clay. Coal borings and the well at the Murphysboro brewery penetrate considerable sand and seldom reach rock at less than 100 feet. The boring at the brewery penetrated 132 feet of drift. An artesian well was sunk at this city many years ago which reached a depth of 1,800 feet. A flow of salt water was struck at about 1,300 feet. The waterworks obtains its supply from Big Muddy River.

At Carbondale the wells are usually obtained at 15 to 20 feet in a sandy clay near the base of the drift. A well at the Newell House entered rock at 22 feet and reached a depth of 50 feet. A well at the electric light plant is reported to have penetrated 44 feet of drift, mainly a clay with few pebbles.

At Elkville, in the northeast part of the county, wells are obtained at about 20 feet from sandy beds associated with the till. A coal boring at this village, reported in the Geology of Illinois, entered rock at 34 feet.

WILLIAMSON COUNTY.

GENERAL STATEMENT.

Williamson County is situated east of Jackson, with Marion as the county seat, and has an area of 440 square miles. The western half of the county is tributary to Big Muddy River and the eastern to Saline River. With the exception of the south border, which is hilly and unglaciated, this county is a low plain covered to a moderate depth with glacial drift. The thickness of the drift appears to be slightly greater than in counties to the north, but it is not often more than 40 feet. The average is probably 25 feet. A capping of silt nearly as compact as the white clay covers the

glacial drift. Where drainage lines are not well developed, the excess of rainfall is largely disposed of by evaporation. The poorest drainage is found in the northwest part of the county, where there is an extensive plain standing but a few feet above the level of Big Muddy River. In this portion of the county wells usually obtain water without entering rock, but in the eastern and southern portions the majority enter rock.

INDIVIDUAL WELLS.

In the vicinity of Marion wells are obtained in sand below till at about 20 feet. They penetrate 5 or 6 feet of white clay, then enter a yellow till which extends to the water-bearing sand. In a few cases blue till is entered at about 20 feet. These conditions prevail over the portion of the county north and west from Marion.

In the portion of the county south and west from Marion low hills with rock nucleus rise above the level of the drift filling, but the plain tracts among these hills are filled to a depth of 50 to 75 feet or more with glacial drift. A well near Cottage Home, in the southwest township of the county, within 3 miles of the glacial boundary, penetrated 68 feet of drift, mainly blue till, and obtained water without entering rock. Several wells in that vicinity are 30 to 40 feet in depth without entering rock.

In the eastern part of the county there are low hills with rock nucleus on which the drift coating is only a few feet in depth, but among these hills the wells often reach a depth of 30 feet without entering rock and are largely through a brown till.

In the unglaciated portion on the south border of the county there are few residents, and these depend chiefly upon cistern water or springs.

SALINE COUNTY.

GENERAL STATEMENT.

Saline County is situated east of Williamson and has an area of 380 square miles, with Harrisburg as the county seat. It is drained by Saline River, whose south fork passes eastward across the southern portion of the county and whose north fork crosses the northeast corner. The portion of the county south of the south fork is an elevated and hilly region, largely unglaciated; the remainder of the county is a low district with small hills

and ridges having rock nuclei, but which rise only 25 to 50 feet above the bordering lowlands. The streams are generally bordered by broad lowlands, portions of which are thinly covered with drift, as are also the low hills and ridges just mentioned. There are probably filled valleys traversing these lowlands, in which the thickness of drift is greater than on the remainder of the county. In this county, as in the neighboring counties on the north and west, the drift is covered with a pebbleless silt several feet in depth. On the hills and ridges this is less compact than the white clay in districts to the north, and the lowland tracts also have usually a more porous silt than the typical white clay.

The glacial drift consists mainly of a brown till, but where it reaches a depth of 30 feet a blue till is usually found at bottom. The wells are often sunk into the rock a short distance, and few strong wells were found which obtain a supply from the drift. Their depth seldom exceeds 40 feet.

INDIVIDUAL WELLS.

At Texas City, in the northeast part of the county, a well sunk by T. W. Overton reached a depth of 302 feet. Water rises within 8 feet of the surface. An inflammable gas was struck at about 240 feet, which is estimated to have a pressure of 75 pounds to the square inch.

At Eldorado wells enter rock at about 20 feet after penetrating a few feet of surface silt and a slightly pebbly clay. Water is usually obtained within 30 or 40 feet. A well at Louis Pettinger's, 2 miles east of Eldorado, on a low drift knoll, reached a depth of 46 feet without entering rock. The lower part was through a blue clay, probably till. A well made by D. Westbrook, on a low drift knoll 2 miles northeast of Eldorado, reached a depth of 40 feet without entering rock, and a similar depth was reached on a knoll 1 mile north of Eldorado in a well made by L. Lyson. These knolls stand only 10 to 20 feet above the bordering plane tracts.

In the vicinity of Raleigh the shallower wells obtain water in drift, but a few wells have been sunk into rock, which is entered at about 30 feet. In the portion of the county west from the meridian of Raleigh there are numerous low hills with rock nuclei, and wells usually enter rock within 10 or 15 feet of the surface. These conditions continue southward past Harrisburg to the elevated ridge on the border of the county. On this ridge the residents depend largely upon cisterns and springs.

GALLATIN COUNTY.

GENERAL STATEMENT.

Gallatin County is situated on the southeast border of the State, a portion of its east boundary being the Wabash and a portion the Ohio River. It has an area of 349 square miles, with Shawneetown as the county seat. The eastern third of the county is so low as to be extensively covered with the sands brought down by the Wabash and Ohio rivers. The northwestern portion which is drained by the north fork of Saline River is largely a low district only 10 to 20 feet higher than the Wabash and Ohio bottoms. There are, however, a few hills with rocky nuclei which rise to a height of 50 feet or more above the bordering lowlands. The southwest corner of the county is occupied by a high and hilly unglaciated tract, the continuation of that noted in southern Saline County. There is a group of hills near Shawneetown which stand 100 to 150 feet above the Ohio River that are entirely surrounded by the low bottoms of the Wabash and Ohio rivers.

With the exception of the hilly district in the southwest part of the county and the group of hills near Shawneetown, just noted, the county is covered with glacial or alluvial deposits. It is probable that the glacial boundary lies a few miles west of the Ohio and Wabash rivers, except at the extreme north border of the county, where it apparently crosses the Wabash. The drift on the lowlands bordering the Wabash and Ohio bottoms is mainly sand, and it is difficult to determine whether it is of direct glacial depositicn. There are in places low knolls and ridges which are composed of sand; they may be largely the product of the wind.

INDIVIDUAL WELLS.

In the vicinity of Omaha, in the northwest part of the county, the drift consists of a typical till. Wells on the low hills and ridges usually enter rock at 15 or 20 feet, but those on the lowlands have penetrated 35 or 40 feet of drift without entering rock. Not infrequently a black muck is found below till on these lowlands at a depth of 20 to 35 feet. Wells near the station in Omaha strike it at about 35 feet, but farther east it is entered at less depth.

Between Omaha and Ridgway a well was driven to a depth of 98 feet without reaching rock, mainly through sand. Wells east and northeast of

Ridgway are in several instances sunk to a depth of over 50 feet, mainly through sand. Wells west and northwest from this village are usually sunk through till, and one well 3 miles west is reported to have reached a depth of 75 feet without entering rock, mainly through till. A blue till was entered at about 25 feet.

Near Cottonwood rock is entered at only 20 feet and the drift is largely sand. Rock is found at slight depth between Cottonwood and New Haven.

At Shawneetown wells usually obtain water at 25 to 40 feet in a sandy gravel An oil boring entered rock at 112 feet. A well at the fair grounds 86 feet in depth did not reach the rock.

THE UNGLACIATED COUNTIES OF SOUTHERN ILLINOIS.

GENERAL STATEMENT.

There are seven counties in the southern end of the State—Hardin, Polk, Johnson, Union, Alexander, Pulaski, and Massac—which are situated outside the limits of the glacial boundary. The four first named are traversed by an elevated ridge, known as the "Ozark uplift," which passes nearly east to west from the Ohio River just below Shawneetown to the Mississippi River at Grand Tower. The crest of this ridge is generally about 400 feet above the Ohio and Mississippi rivers, but occasional knobs along it reach an elevation of 500 and even 600 feet above the river. The most rugged portion of the ridge is found in the northern 6 or 8 miles of these counties and extends slightly into the counties on the north—Jackson, Williamson, Saline, and Gallatin, as noted above.

South from this elevated and rugged portion of the ridge there is a somewhat hilly tract with lower altitude, which extends to the lowlands covered by Tertiary gravel, which occupy much of the three southern counties of the State—Alexander, Pulaski, and Massac.

Although not covered by the ice sheet, this district has received deposits of glacial age which affect to some extent the condition of drainage and the character of the soil.

The Ohio and Mississippi valleys have been filled with deposits of sand and fine gravel to a depth probably not less than 100 feet. There are also alluvial deposits outside the line of the present Ohio which were probably made at the time of the filling of the main valleys. A broad valley, known

as the Cache, now largely a cypress swamp, leads westward from northwestern Massac County across northern Pulaski and then turns south into the Ohio along the line of Alexander and Pulaski counties. From the head of this swamp there is a well-defined connection with the Ohio River in a low plain leading southeast to Metropolis, across the central portion of Massac County. This plain has been built to a level about 70 to 75 feet above the Ohio River, or 20 to 25 feet above the highest present flood stages of the stream. Its freshness of topography is decidedly in contrast with that of the bordering Tertiary formations, in which there has been great erosion. As noted above (p. 528), this channel was probably silted up either at the Illinoian or the Iowan stage of glaciation.

In addition to the alluvial deposits found in the valleys and lowlands there is a coating of loess found on all except the most rugged portions of the uplands. This loess has a general thickness of about 12 feet on the border of the Ohio and fully twice that amount on the border of the Mississippi, while in the interior portions, as on the glaciated districts to the north, its thickness is only 5 or 6 feet. Whether the loess originally covered the highest and most rugged parts of this ridge is not known. If originally present it has now been largely removed. A more critical study may perhaps develop decisive evidence on this point.

INDIVIDUAL WELLS.

On the most rugged portions of the ridge there are very few residents and these depend chiefly upon cistern water. On the lower tract, between the crest of the ridge and the Cache, there is a limestone district in which wells are usually obtained at 40 to 60 feet or less. In the district covered by Tertiary deposits wells are usually found at moderate depth, seldom exceeding 40 feet. The wells on the lowland connecting the Ohio with the Cache near Metropolis have in several instances reached a depth of 60 to 75 feet, but in the neighborhood of the Cache they obtain water at much shallower depth, often being but 15 to 20 feet deep. Along the Mississippi Valley the wells are usually driven to a depth of 30 or 40 feet. It is reported that Mr. Bolin Sublette, an early settler in Union County, dug a well near Wolf Lake Station to a depth of about 80 feet, reaching a level at least 50 feet below the low water of the Mississippi River. It is

also reported that a log was found near the bottom. This well indicates that the present stream is flowing at a level considerably higher than the preglacial rock floor.

At Anna the wells are 20 to 60 feet in depth, the majority being about 40 feet, and obtain water in limestone. The city authorities are considering the advisability of constructing waterworks. The best wells are estimated to have a capacity of about 100,000 gallons a day. The source for the public water supply might therefore be found in these wells.

At Vienna wells are obtained at 25 to 60 feet in limestone, the usual depth being about 50 feet. An average well is estimated to yield about 12 barrels of water a day.

The village of Thebes stands in a portion of the Mississippi Valley which is postglacial, and wells obtain water at the top of the rock at a depth of only 20 feet. The residents depend largely upon cistern water.

At Cairo the waterworks are supplied from the Ohio River. Excavated wells are not allowed within the city limits. Driven wells have been sunk to depths of 70 to 200 feet. No solid rock is reached at the latter depth. The city engineer reports that good water is obtained at about 70 feet. The following section of a boring for a bridge, by the Illinois Central Railroad Company, was furnished by the city engineer. The surface elevation is 45 feet above low water at the mouth of the Ohio. The boring therefore reaches a level 80 feet below the low-water mark:

Section of boring for bridge of Illinois Central Railroad at Cairo, Illinois.

	Feet.
Mud and sand	15
Fine sand	40
Coarse sand and gravel	30
Coarse sand, gravel, and fragments of sand rock	15
Fine sand and gravel	10
Fine white sand	15
Total depth	125

This boring should be compared with borings made by the United States Army Engineers at points between Cairo and Vicksburg.[1]

At Metropolis the public water supply is pumped from the Ohio River, but there are numerous wells about 40 feet in depth. These wells

[1] See reports of the Chief of Engineers, United States Army, for 1877, 1878, and 1879; also Report of Mississippi River Commission, 1881, pp. 171-239.

are through a silt or clay for a few feet in their upper portion, but the greater part of the section is sand. Gravel is entered near the bottom, which is probably Tertiary. As noted above, wells on the low plain leading from Metropolis northwest to the Cache are occasionally sunk to a depth of 75 feet. They are largely through a fine sand, but enter gravel at bottom, probably Tertiary.

At Olmsted wells obtain water in some cases at 35 feet, but a well on a low hill northeast of the station, standing 140 feet above the Ohio, reached a depth of 81 feet. The lower 60 feet was entirely a Tertiary gravel.

At Brooklyn (Pellonia post-office) the river bank is about 45 feet above low water of the Ohio and there is Tertiary gravel to within 15 feet of the top. Wells obtain water in this gravel near the river level.

In the vicinity of Rosebud, in Pope County, where the altitude is nearly 250 feet above the river, there is a heavy deposit of Tertiary gravel in which wells have occasionally reached a depth of 100 feet without entering rock, but on neighboring farms at similar altitude rock may be entered at 25 or 50 feet.

At Golconda wells are usually obtained in the Ohio bottoms at a depth of 30 to 40 feet. A well made by Mr. George Boos, at a level probably 65 feet above low water in the Ohio, reached a depth of 136 feet without entering rock. The best water vein was at about 40 feet. Wells on the bluff also reach water at only 30 or 40 feet, in sandstone.

CHAPTER XV.

SOILS.

SOURCES OF SOIL MATERIAL.

The principal sources from which the soils of the region under discussion are derived are the glacial drift and the loess, with its associated silts of glacial age. The underlying rocks are indirectly a source of much material, since their decomposed surface portions were incorporated in the drift, but they constitute a minor source so far as direct contribution is concerned. Lakes and streams attending the melting of the ice sheet have deposited material in considerable amount, and it is thought that the wind also has been influential in distributing fine material over portions of the surface of the region. The present streams are also a source for soil in the districts over which they spread in their flood stages.

The preceding discussion has shown that portions of the surface of this region date from the Iowan stage of glaciation, namely, the portions covered by the Iowan loess and associated silts, and the portion in which the Iowan till sheet forms the surface. These deposits form the surface of considerably more than one-half the region. In the remainder of the region the Wisconsin drift constitutes the main part of the surface, though small areas have been occupied by lakes and streams since the withdrawal of the Wisconsin ice sheet. The area covered by Lake Chicago is the most conspicuous illustration.

CLASSES OF SOIL.

Inasmuch as soils are largely composed of fragments of rock material, they are naturally dependent to a certain degree upon the character of the rock from which they are chiefly derived. This is especially true in unglaciated regions, but in glaciated regions also the soil is found to depend upon the character of the underlying deposits. There are several modes of classification in use, based usually upon either chemical constitution or physical texture or characteristics. The classification which seems to best serve our purpose is based mainly upon physical characteristics. This classification also sets forth what appear to be the characteristics of chief importance. The elaborate investigations made by Prof. Milton Whitney, of the United

States Department of Agriculture, on the Maryland soils indicate that the texture and physical conditions of the soils are of even more importance than the chemical composition. On this matter Professor Whitney has written as follows:[1]

The prevailing ideas of plant nutrition have been based mainly upon the chemical composition of soils. When it was found that the chemical composition of a soil and plant did not show what was lacking in the soil for a large crop, it was held that only a small part of the plant food in the soil is at any one time in a form of combination which is available to plants; that the available plant food never accumulates as such in the soil, but quickly reverts to more insoluble forms, which are unavailable to plants. According to this idea the exhaustion of soils by continued cropping is due to the actual loss of available plant food removed by the crop or converted into an unavailable form by chemical changes in the soil. The chief use of fertilizers is to supply the plant with food which the soil fails to furnish. The reason certain plants do better on certain kinds of soil is assumed to be due to the fact that plants vary greatly in their powers of gathering their food from the soil and air, and that thus a rye plant would do well on a soil too poor to give a good yield of wheat.

Our investigations on the Maryland soils seem to show, however, that the texture and the physical conditions of the soil are of more importance than the chemical composition. It appears that under favorable conditions of moisture and temperature plants can readily gather sufficient food material from nearly all soils; but if these conditions of moisture and heat are changed, the development of the plant will be greatly changed and it will take up more or less food from the soil. Soils differ greatly in their texture—that is, in the amount of sand and clay which they contain—and, as we have seen, this controls very largely the supply of moisture which they can maintain for the crop with a given amount of rainfall. If there are 4 inches of rainfall a month, the coarse sandy soil will allow most of this to run through very quickly, so that there may not be more than 5 or 6 per cent of water held in the soil for the crop, or, say, about 100 tons of water per acre 1 foot deep; and when this water is used up, the soil has comparatively little power to draw up more water from below for the use of the crops. With a compact clay soil, on the other hand, the water passes downward very slowly, and the soil will maintain about 18 or 20 per cent of its weight of water for the crop, or about 400 or 500 tons of water per acre 1 foot deep. In the dry season, also, the clay soil has more power of drawing up water from below and maintaining this supply. If a florist should give a plant four times as much water as he gives another plant of the same kind, the two plants would develop very differently, and he uses this constantly to produce any kind of development he desires. If it is desired to have the plant flower or fruit, the soil is kept rather dry and cool. If it is desired to produce large leafy plants, the soil is kept much wetter and warmer. To have equal success with different kinds of plants the amount of water must be carefully regulated according to the needs of the plant. Some plants require a much more abundant supply of water than others. This control of moisture and temperature is far more important than the mere chemical composition of the soil.

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[1] Rept. Illinois Board of World's Fair Commissioners, 1895, pp. 94–96.

The texture of our various soils being different, they are enabled to maintain a variety of conditions of moisture, and they partake somewhat of these artificial conditions in a greenhouse, the conditions in each of the soils being best suited to the needs of certain classes of plants.

The amount of moisture which a soil can maintain for a crop, under given climatic conditions, will depend mainly, (1) upon the amount of space in the soil in which water can enter; (2) upon the extent of subdivision of this space—that is, upon the number of grains of sand and clay there is in a given volume of soil; (3) upon the arrangement of these grains, for, as already remarked, if the grains are symmetrically arranged, so that the spaces shall all be of uniform size, water will move through the soil much slower than if the spaces are of very unequal sizes; (4) upon the amount and condition of the organic matter in the soils. The grains of clay are so exceedingly small that their number vastly exceeds the number of the grains of sand and silt, so that the percentage of clay practically determines the extent of subdivision of the space, and it is thus the most important ingredient of the soil.

In Illinois and adjacent districts the following classes of soil are represented: (1) residuary soils, or soils formed from the underlying rock; (2) stony, or glacial clays; (3) gravelly soils; (4) sandy soils; (5) loess, or silt rapidly pervious to water; (6) silt slowly pervious to water; (7) fine silts nearly impervious to water; (8) peaty or organic material. A tabular statement is here presented which shows the origin or mode of deposition and the areal distribution in Illinois of the several classes of soil:[1]

Table of soils of Illinois.

Variety.	Origin or mode of deposition.	Areal distribution.
Residuary	Decay of the underlying rocks.	Driftless portion of the State wherever the loess as well as the glacial drift is absent.
Glacial clay	Glacial	Mainly in the northeastern quarter of the State, where loess and silts are generally absent. The Shelbyville moraine forms the southern boundary and chiefly the western boundary, but in northern Illinois glacial clays form the soil on the Iowan drift area between the Shelbyville moraine and the loess of the Mississippi Valley.
Gravelly	Glacial overwash, streams, lakes.	With the glacial clay in the northeastern part of the State, and along streams leading away from the Shelbyville and later moraines. This variety of soil includes gravel knolls and ridges, overwash gravel plains, terraces, and beaches.

[1] This table was published by the writer in the Report of Illinois Board of World's Fair Commissioners, 1895.

Table of soils of Illinois—Continued.

Variety.	Origin or mode of deposition.	Areal distribution.
Sandy	Glacial drainage, streams, lakes, winds.	Mainly in basins along the Kankakee, Green, and lower Illinois rivers; old lake bottom and raised beaches near Chicago; also on bottom lands, and fringing in many places the low bluffs of streams, and locally developed on areas of glacial formations.
Silts pervious to water (chiefly the typical loess).	In part by slowly flowing waters; probably in part by wind.	Along the Mississippi, lower Illinois, lower Wabash, and lower Ohio rivers; also between the Illinois and the Mississippi from the Green River Basin south to the latitude of Peoria, and in the basin of the Big Bureau Creek, in Bureau County.
Silts slowly pervious to water.	In part by slowly flowing waters; probably in part by wind.	Mainly in west-central Illinois, west of a line connecting Alton, Litchfield, Pana, Decatur, and Peoria; also on the eastern border of the Mississippi Valley loess belt, in the northern part of the State.
Silts nearly impervious to water. (Two kinds, namely, white clays and gumbo)	Nearly still waters; perhaps wind in part.	White clays cover much of southern Illinois south of the Shelbyville moraine, as far west as the Mississippi loess, east to the Wabash loess and south to the Ohio River loess. Gumbo is found on some bottom lands along the main rivers.
Peaty and marly	Vegetal accumulations and shell deposits.	Locally over the greater part of the State wherever drainage is imperfect. Peat is rare south of the latitude of Springfield, but it abounds in the northeastern quarter of the State, in bogs. Marl deposits are less extensive than peat, but are fully as widespread.

RESIDUARY SOILS.

The residuary soils show variations which correspond in a rude way with variations in the structure of the rocks from which they are derived, there being in regions underlain by shale or limestone a more compact and adhesive soil than in sandstone regions. Each class of limestone has its own peculiar soil, and soils derived from shales range from stiff clay to a sandy material. A complete analysis of the nature of the differences displayed by the several classes of residuary soils has not been made. With proper rotation of crops these soils are usually fertile, but otherwise they become exhausted sooner than soils formed on glacial drift.

BOWLDER-CLAY SOILS.

The soils formed on the bowlder clay are usually very productive, being composed of a varied rock material, a large percentage of which is in a sufficiently fine state of division to be available for plant food. Several mechanical analyses of this class of soil were made under the direction of Prof. Milton Whitney, the results of which are given on a preceding page (p. 163). Professor Whitney has made the following statements regarding the bowlder-clay soils of Illinois:[1]

> The texture of the bowlder-clay lands, as shown by mechanical analysis, corresponds very closely with the wheat and grass lands of Maryland, although none of the samples are so rich in clay as the limestone soils of that State. There is this to be considered, however, that there is a larger amount of volatile matter in the Illinois soils, showing that they contain probably twice as much organic matter as the Maryland soils. This would tend to make them more productive than soils otherwise similar in texture.

As to the actual tests of the bowlder-clay soils it may be said that, in general, all classes of grains and fruits suitable to the latitude will flourish; especially where the surface is rolling or well drained. On the flat tracts corn and grass are exceptionally productive.

GRAVELLY SOILS.

Gravelly soils are varied in their method of deposition, occurring in lake beaches and along streams, in drift knolls and ridges, and beneath plains not now occupied by streams. In the last-named situation the plains are usually so related to the drift ridges as to show that they were occupied by glacial waters. The beaches have generally a poor soil, but the gravel terraces along streams, especially those of glacial age, have as a rule a capping of loam several feet thick, which renders them productive. The same is often true of gravelly knolls and ridges. On the whole the soils underlain by gravel possess more fertility than do sandy soils. This superiority is, however, due to the capping of loam which constitutes the soil, or, as in the drift knolls and ridges, to an admixture of clay or earthy material with the surface portion of the gravel. The coarse fragments in the gravel can furnish but little sustenance to crops, although, by weathering, the stones may yield rich material to the soils and furnish a greater variety of plant food than could be obtained from siliceous sand.

[1] Report of Illinois Board of World's Fair Commissioners, p. 100.

SANDY SOILS.

The sandy soils, though apparently much alike in structure, are varied in their methods of deposit. They occur in the beaches along the borders of Lake Michigan, in the valley bottoms of the main streams, on the bluffs and along the borders of the streams which lead away from the newer drift district, in basins within the newer drift district (as the Kankakee and Illinois-Vermilion), and to a limited extent in the moraines. There is also an extensive development of sand in northwestern Illinois, in the Green River Basin and the bordering districts, as far north as northern Whiteside County. Where the sand is of medium to coarse grade it is usually rather barren, but where fine, as in the eastern portion of the sandy belt bordering the Illinois in Tazewell and Mason counties, it is productive. Within the sand-covered districts there are more or less extensive tracts of wet, mucky land between sand ridges. This, where artificially drained, has often proved very productive. There are districts where the loess assumes a sandy phase, but in these places the sand is very fine, so fine that individual grains can scarcely be detected by the eye, and the fertility is about as great as in the typical loess.

BLUFF LOESS SOILS.

The very porous phase of the loess within the region under discussion is confined mainly to the borders of the Mississippi, Illinois, Ohio, and Wabash rivers, extending back usually but a few miles from the streams. It may therefore properly be called the "bluff loess." There is, however, a porous loess along the south border of the Green River Basin, and in general the loess between the Mississippi and Illinois rivers is more porous than on uplands to the west or east. In southern Illinois the loess becomes a compact white clay within a few miles back from the Mississippi, Ohio, and Wabash rivers, but in western Illinois it changes to the slowly pervious silt which is more productive than the white clay. The very porous loess which borders the main streams will permit roots to penetrate readily to a great depth, there being observations of penetration to 25 or 30 feet. It is, however, usually of such a texture that water rises in it by capillarity in dry seasons and adequately supplies the crops.

The mechanical analyses of specimens of the bluff loess made under the direction of Professor Whitney have been presented in tabular form in

connection with the discussion of the loess (p. 161). Concerning these samples Professor Whitney remarks:[1]

> They are lighter in texture than the best wheat lands of Maryland, although they have rather more organic matter to balance the low percentage of clay. They are more like our fruit and tobacco lands, although the higher percentage of volatile matters indicate that they are rather more retentive of moisture.

The loess differs markedly from the agricultural lands of Maryland in the relative amounts of clay in the soil and subsoil. It is the rule of the Maryland agricultural lands to present a larger amount of clay in the subsoil than in the soil, but in the loess the reverse appears to be the case, as the following table indicates:

Percentage of clay in soil and subsoil of Illinois loess.

Locality.	Soil (per cent of clay).	Subsoil (per cent of clay).
Virginia City, No. 1	15.34	6.75
Virginia City, No. 2	15.15	7.10
Carrollton	23.65	12.52
Rock Island	12.08	------------
Gladstone	------------	8.31

The bluff loess yields fair crops of all kinds, but is especially valuable for fruit, both orchard and small fruits. Its superiority in fertility over the white clay and finer silts seems due to the physical condition of porosity. Nothing has been found to indicate that it contains a better supply of plant food. Moreover, the fertility of the latter is made certain by the rich growth of such crops as will flourish in a compact soil.

SILTS SLOWLY PERVIOUS TO WATER.

The silts slowly pervious to water embrace the rich black soil district of the western portion of Illinois. The southern boundary lies near a line connecting Alton, Litchfield, and Pana. The eastern boundary of the main district may be placed at the border of the newer or Wisconsin drift. The northern boundary is near the south border of the Green River Basin, while the western boundary is found in the loess that borders the Mississippi. Through this district there passes the belt of porous loess

[1] Report of Illinois Board of World's Fair Commissioners, p. 101.

which borders the Illinois, a belt several miles in width. Aside from this main district, there is considerable silt of this class between the Rock and Mississippi rivers, in northern Illinois, capping the earlier or Illinoian drift sheet.

On the newer (Wisconsin) drift, as stated above, silts slowly pervious to water cover large districts in central and eastern Illinois to a depth of several feet. In northeastern Illinois such a silt capping is not a common feature.

Wherever silts of this class occur the vegetation is usually prairie grass, and there is a blackening of the soil by humus to a depth of several inches, often 2 feet or more. This class of silts affords a highly productive soil, one which will yield fair returns even under most careless methods of farming. Corn and grass are the staple products, but other crops have a fair yield.

FINE SILTS NEARLY IMPERVIOUS TO WATER.

The fine silts nearly impervious to water are of two classes—white clay and "gumbo." The first class covers the uplands of much of southern Illinois. The second is common in portions of modern river valleys, remote from the current and subject to overflow only in periods of extreme high water, and has great extent along the Illinois and Mississippi river bottoms. A less compact silt, found in river bottoms, is known as potato land.

The white clay is a pale-colored deposit, scarcely at all blackened by humus. It covers the greater part of Illinois south from a line running eastward from Litchfield, Illinois, to the Wabash Valley, near Terre Haute, Indiana. It also covers much of Clay, Vigo, and Sullivan counties, Indiana. It is so poorly drained that much of the water stands on the surface until removed by evaporation, while in seasons of drought scarcely enough water rises from below to supply the loss from evaporation. In the southeastern portion of Illinois and southwestern part of Indiana there is, however, a looser soil, less easily influenced either by excess or deficiency of rainfall. In those districts the surface is hilly and the white clay is much more eroded than in flat tracts. The drift is so thin, also, that the rock, in many places, comes sufficiently near the surface to have become uncovered by erosion and thus to give character to the soil.

There are extensive districts in south-central Illinois with very flat surface where the white clay soil is underlain at a depth of a few inches by a

ferruginous crust or ochery clay, which is exceedingly refractory, giving very slow access to air or water. With this exception, however, the crust is either absent or is so low down that it does not seriously affect the soil. Aside from corn, which is liable to be injured by autumn droughts, the leading crops of the State do fairly well. Wheat yields as well as anywhere in the State, while orchards and small fruits bring very profitable returns. The soil needs careful attention, but there is every indication that where properly cared for it will become as profitable for agriculture as the soils which now enjoy a better reputation.

Concerning the analyses of the samples of white clay and also of the more porous upland loess (see p. 162) Professor Whitney remarks:[1]

Of the upland loess there are two types—those which are pervious to water and which are valuable agricultural lands; those which are compact and almost impervious to water, locally known as white clays, which are so very retentive of moisture as to be always wet and of less agricultural value. The mechanical analysis shows that these two types of land are almost identical in texture, and that the white clays (1321, 1342, 1343, and 1345) have no more clay than the other samples of upland loess, which are considered very fertile lands. The wetness of these white clay lands, therefore, is not due to the fact that they contain more clay, but it must be ascribed to some other cause. They contain no more organic matter, so that it can not be due to an excessive amount of this material. It must be due, therefore, to one of two causes—either that there is a hardpan or a layer of impervious clay underlying these lands which retards the descent of the water and prevents the excess of rainfall being carried down, or it may be due to a difference in the arrangement in the grains. Our laboratory experiments do not seem to indicate that there is any material difference in the arrangement of the grains in these two classes of soils, but this can only be determined with certainty by investigation of the soils in their natural position in the field. If the pervious character of the white clays is due to a difference in the arrangement of the grains, the lands ought to be underdrained so that the excess of water may be artificially removed, or the trouble may be greatly alleviated by liming the land, which will tend to make it more loamy and less retentive of moisture. The effect of kainit and of some of the phosphates would probably have a similar effect on the land if applied regularly for a number of years. If the soils are impervious because of a hardpan or a layer of impervious clay 3 or 4 feet below the surface, then fertilizers will do very little to correct the evil unless the lands are systematically underdrained.

PEATY AND ORGANIC SOILS.

The peaty and organic soils occur in basins or in poorly drained tracts where rank vegetation becomes submerged at certain seasons and is thus prevented from atmospheric decay. This class of soils is much more

[1] Report of Illinois Board of World's Fair Commissioners, pp. 101–102.

abundant in the northern part of the region than the southern. Peat bogs occur, however, south of the center of the State of Illinois.

Many bogs are underlain by shell marl as well as by peat. The marl is seldom sufficiently pure or abundant to be used in the manufacture of lime. The marl beds are especially abundant on the south and east borders of Lake Michigan.

In many instances the bogs when drained, the peat being given time to ripen and become warm, yield large crops of potatoes and other garden truck. Wheat or other crops requiring mineral food in the ripening of their grains can scarcely be expected to grow on such soil until it becomes charged with earthy material by natural or artificial processes.

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[Monograph XXXVIII.]

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93. Some Insects of Special Interest from Florissant, Colorado, and Other Points in the Tertiaries of Colorado and Utah, by Samuel Hubbard Scudder. 1892. 8°. 35 pp. 3 pl. Price 5 cents.

94. The Mechanism of Solid Viscosity, by Carl Barus. 1892. 8°. 138 pp. Price 15 cents.

95. Earthquakes in California in 1890 and 1891, by Edward Singleton Holden. 1892. 8°. 31 pp. Price 5 cents.

96. The Volume Thermodynamics of Liquids, by Carl Barus. 1892. 8°. 100 pp. Price 10 cents.

97. The Mesozoic Echinodermata of the United States, by W. B. Clark. 1893. 8°. 207 pp. 50 pl. Price 20 cents.

98. Flora of the Outlying Carboniferous Basins of Southwestern Missouri, by David White. 1893. 8°. 139 pp. 5 pl. Price 15 cents.

99. Record of North American Geology for 1891, by Nelson Horatio Darton. 1892. 8°. 73 pp. Price 10 cents.

100. Bibliography and Index of the Publications of the U. S. Geological Survey, 1879-1892, by Philip Creveling Warman. 1893. 8°. 495 pp. Price 25 cents.

101. Insect Fauna of the Rhode Island Coal Field, by Samuel Hubbard Scudder. 1893. 8°. 27 pp. 2 pl. Price 5 cents.

102. A Catalogue and Bibliography of North American Mesozoic Invertebrata, by Cornelius Breckinridge Boyle. 1892. 8°. 315 pp. Price 25 cents.

103. High Temperature Work in Igneous Fusion and Ebullition, chiefly in Relation to Pressure, by Carl Barus. 1892. 8°. 57 pp. 9 pl. Price 10 cents.

104. Glaciation of the Yellowstone Valley north of the Park, by Walter Harvey Weed. 1893. 8°. 41 pp. 4 pl. Price 5 cents.

105. The Laramie and the Overlying Livingstone Formation in Montana, by Walter Harvey Weed, with Report on Flora, by Frank Hall Knowlton. 1893. 8°. 68 pp. 6 pl. Price 10 cents.

106. The Colorado Formation and its Invertebrate Fauna, by T. W. Stanton. 1893. 8°. 288 pp. 45 pl. Price 20 cents.

107. The Trap Dikes of the Lake Champlain Region, by James Furman Kemp and Vernon Freeman Marsters. 1893. 8°. 62 pp. 4 pl. Price 10 cents.

108. A Geological Reconnoissance in Central Washington, by Israel Cook Russell. 1893. 8°. 108 pp. 12 pl. Price 15 cents.

109. The Eruptive and Sedimentary Rocks on Pigeon Point, Minnesota, and their Contact Phenomena, by William Shirley Bayley. 1893. 8°. 121 pp. 16 pl. Price 15 cents.

110. The Paleozoic Section in the Vicinity of Three Forks, Montana, by Albert Charles Peale. 893. 8°. 56 pp. 6 pl. Price 10 cents.

111. Geology of the Big Stone Gap Coal Fields of Virginia and Kentucky, by Marius R. Campbell. 1893. 8°. 106 pp. 6 pl. Price 15 cents.

112. Earthquakes in California in 1892, by Charles D. Perrine. 1893. 8°. 57 pp. Price 10 cents.

113. A Report of Work done in the Division of Chemistry during the Fiscal Years 1891–'92 and 1892–'93. F. W. Clarke, Chief Chemist. 1893. 8°. 115 pp. Price 15 cents.

114. Earthquakes in California in 1893, by Charles D. Perrine. 1894. 8°. 23 pp. Price 5 cents.

115. A Geographic Dictionary of Rhode Island, by Henry Gannett. 1894. 8°. 31 pp. Price 5 cents.

116. A Geographic Dictionary of Massachusetts, by Henry Gannett. 1894. 8°. 126 pp. Price 15 cents.

117. A Geographic Dictionary of Connecticut, by Henry Gannett. 1894. 8°. 67 pp. Price 10 cents.

118. A Geographic Dictionary of New Jersey, by Henry Gannett. 1894. 8°. 131 pp. Price 15 cents.

119. A Geological Reconnoissance in Northwest Wyoming, by George Homans Eldridge. 1894. 8°. 72 pp. Price 10 cents.

120. The Devonian System of Eastern Pennyslvania and New York, by Charles S Prosser. 1894. 8°. 81 pp. 2 pl. Price 10 cents.

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122. Results of Primary Triangulation, by Henry Gannett. 1894. 8°. 412 pp. 17 pl. Price 25 cents.

123. A Dictionary of Geographic Positions, by Henry Gannett. 1895. 8°. 183 pp. 1 pl. Price 15 cents.

124. Revision of North American Fossil Cockroaches, by Samuel Hubbard Scudder. 1895. 8°. 176 pp. 12 pl. Price 15 cents.

125. The Constitution of the Silicates, by Frank Wigglesworth Clarke. 1895. 8°. 109 pp. Price 15 cents.

126. A Mineralogical Lexicon of Franklin, Hampshire, and Hampden counties, Massachusetts, by Benjamin Kendall Emerson. 1895. 8°. 180 pp. 1 pl. Price 15 cents.

127. Catalogue and Index of Contributions to North American Geology, 1732–1891, by Nelson Horatio Darton. 1896. 8°. 1045 pp. Price 60 cents.

128. The Bear River Formation and its Characteristic Fauna, by Charles A. White. 1895. 8°. 108 pp. 11 pl. Price 15 cents.

129. Earthquakes in California in 1894, by Charles D. Perrine. 1895. 8°. 25 pp. Price 5 cents.

130. Bibliography and Index of North American Geology, Paleontology, Petrology, and Mineralogy for 1892 and 1893, by Fred Boughton Weeks. 1896. 8°. 210 pp. Price 20 cents.

131. Report of Progress of the Division of Hydrography for the Calendar Years 1893 and 1894, by Frederick Haynes Newell, Topographer in Charge. 1895. 8°. 126 pp. Price 15 cents.

132. The Disseminated Lead Ores of Southeastern Missouri, by Arthur Winslow. 1896. 8°. 31 pp. Price 5 cents.

133. Contributions to the Cretaceous Paleontology of the Pacific Coast: The Fauna of the Knoxville Beds, by T. W. Stanton. 1895. 8°. 132 pp. 20 pl. Price 15 cents.

134. The Cambrian Rocks of Pennsylvania, by Charles Doolittle Walcott. 1896. 8°. 43 pp. 15 pl. Price 5 cents.

135. Bibliography and Index of North American Geology, Paleontology, Petrology, and Mineralogy for the Year 1894, by F. B. Weeks. 1896. 8°. 141 pp. Price 15 cents.

136. Volcanic Rocks of South Mountain, Pennsylvania, by Florence Bascom. 1896. 8°. 124 pp. 28 pl. Price 15 cents.

137. The Geology of the Fort Riley Military Reservation and Vicinity, Kansas, by Robert Hay. 1896. 8°. 35 pp. 8 pl. Price 5 cents.

138. Artesian-Well Prospects in the Atlantic Coastal Plain Region, by N. H. Darton. 1896. 8° 228 pp. 19 pl. Price 20 cents.

139. Geology of the Castle Mountain Mining District, Montana, by W. H. Weed and L. V. Pirsson. 1896. 8°. 164 pp. 17 pl. Price 15 cents.

140. Report of Progress of the Division of Hydrography for the Calendar Year 1895, by Frederick Haynes Newell, Hydrographer in Charge. 1896. 8°. [illegible] pp. Price 25 cents.

141. The Eocene Deposits of the Middle Atlantic Slope in Delaware, Maryland, and Virginia, by William Bullock Clark. 1896. 8°. 167 pp. 40 pl. Price 15 cents.

142. A Brief Contribution to the Geology and Paleontology of Northwestern Louisiana, by T. Wayland Vaughan. 1896. 8°. 65 pp. 4 pl. Price 10 cents.

143. A Bibliography of Clays and the Ceramic Arts, by John C. Branner. 1896. 8°. 114 pp. Price 15 cents.

144. The Moraines of the Missouri Coteau and their Attendant Deposits, by James Edward Todd. 1896. 8°. 71 pp. 21 pl. Price 10 cents.

145. The Potomac Formation in Virginia, by W. M. Fontaine. 1896. 8°. 149 pp. 2 pl. Price 15 cents.

146. Bibliography and Index of North American Geology, Paleontology, Petrology, and Mineralogy for the Year 1895, by F. B. Weeks. 1896. 8°. 130 pp. Price 15 cents.

147. Earthquakes in California in 1895, by Charles D. Perrine, Assistant Astronomer in Charge of Earthquake Observations at the Lick Observatory. 1896. 8°. 23 pp. Price 5 cents.

148. Analyses of Rocks, with a Chapter on Analytical Methods, Laboratory of the United States Geological Survey, 1880 to 1896, by F. W. Clarke and W. F. Hillebrand. 1897. 8°. 306 pp. Price 20 cents.

149. Bibliography and Index of North American Geology, Paleontology, Petrology, and Mineralogy for the Year 1896, by Fred Boughton Weeks. 1897. 8°. 152 pp. Price 15 cents.

150. The Educational Series of Rock Specimens collected and distributed by the United States Geological Survey, by Joseph Silas Diller. 1898. 8°. 398 pp. 47 pl. Price 25 cents.

151. The Lower Cretaceous Gryphæas of the Texas Region, by R. T. Hill and T. Wayland Vaughan. 1898. 8°. 139 pp. 25 pl. Price 15 cents.

152. A Catalogue of the Cretaceous and Tertiary Plants of North America, by F. H. Knowlton. 1898. 8°. 247 pp. Price 20 cents.

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154. A Gazetteer of Kansas, by Henry Gannett. 1898. 8°. 246 pp. 6 pl. Price 20 cents.

155. Earthquakes in California in 1896 and 1897, by Charles D. Perrine, Assistant Astronomer in Charge of Earthquake Observations at the Lick Observatory. 1898. 8°. 47 pp. Price 5 cents.

156. Bibliography and Index of North American Geology, Paleontology, Petrology, and Mineralogy for the Year 1897, by Fred Boughton Weeks. 1898. 8°. 130 pp. Price 15 cents.

160. A Dictionary of Altitudes in the United States (Third Edition), compiled by Henry Gannett. 1899. 8°. 775 pp. Price 40 cents.

161. Earthquakes in California in 1898, by Charles D. Perrine, Assistant Astronomer in Charge of Earthquake Observations at the Lick Observatory. 1899. 8°. 31 pp. 1 pl. Price 5 cents.

In preparation:

157. The Gneisses, Gabbro-Schists, and Associated Rocks of Southeastern Minnesota, by C. W. Hall.

158. The Moraines of southeastern South Dakota and their Attendant Deposits, by J. E. Todd.

159. The Geology of Eastern Berkshire County, Massachusetts, by B. K. Emerson.

WATER-SUPPLY AND IRRIGATION PAPERS.

By act of Congress approved June 11, 1896, the following provision was made:

"*Provided*, That hereafter the reports of the Geolo ical Survey in relation to the gauging of streams and to the methods of utilizing the water resources may be prin ed in octavo form, not to exceed one hundred pa es in length and five thousand copies in number; one thousand copies of which shall be for the official us of the Geological Survey, one thousand five hundred copies shall be delivered to the Senate, and two thousand five hundred copies shall be delivered to the House of Representatives, for distribution."

Under this law the following papers have been issued:

1. Pumping Water for Irrigation, by Herbert M. Wilson. 1896. 8°. 57 pp. 9 pl.
2. Irrigation near Phœnix, Arizona, by Arthur P. Davis. 1897. 8°. 97 pp. 31 pl.
3. Sewage Irrigation, by George W. Rafter. 1897. 8°. 100 pp. 4 pl.
4. A Reconnoissance in Southeastern Washington, by Israel Cook Russell. 1897. 8°. 96 pp. 7 pl.
5. Irrigation Practice on the Great Plains, by Elias Branson Cowgill. 1897. 8°. 39 pp. 12 pl.
6. Underground Waters of Southwestern Kansas, by Erasmus Haworth. 1897. 8°. 65 pp. 12 pl.
7. Seepage Waters of Northern Utah, by Samuel Fortier. 1897. 8°. 50 pp. 3 pl.
8. Windmills for Irrigation, by Edward Charles Murphy. 1897. 8°. 49 pp. 8 pl.
9. Irrigation near Greeley, Colorado, by David Boyd. 1897. 8°. 90 pp. 21 pl.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker. 1898. 8°. 51 pp. 11 pl.
11. River Heights for 1896, by Arthur P. Davis. 1897. 8°. 100 pp.
12. Water Resources of Southeastern Nebraska, by Nelson H. Darton. 1898. 8°. 55 pp. 21 pl.
13. Irrigation Systems in Texas, by William Ferguson Hutson. 1898. 8°. 67 pp. 10 pl.
14. New Tests of Certain Pumps and Water-Lifts used in Irrigation, by Ozni P. Hood. 1889. 8°. 91 pp. 1 pl.
15. Operations at River Stations, 1897, Part I. 1898. 8°. 100 pp.
16. Operations at River Stations, 1897, Part II. 1898. 8°. 101-200 pp.
17. Irrigation near Bakersfield, California, by C. E. Grunsky. 1898. 8°. 96 pp. 16 pl.
18. Irrigation near Fresno, California, by C. E. Grunsky. 1898. 8°. 94 pp. 14 pl.
19. Irrigation near Merced, California, by C. E. Grunsky. 1899. 8°. 59 pp. 11 pl.
20. Experiments with Windmills, by T. O. Perry. 1899. 8°. 97 pp. 12 pl.

21. Wells of Northern Indiana, by Frank Leverett. 1899. 8°. 82 pp. 2 pl.
22. Sewage Irrigation, Part II, by George W. Rafter. 1899. 8°. 100 pp. 7 pl.
23. Water-Right Problems of Bighorn Mountains, by Elwood Mead. 1899. 8°. 62 pp. 7 pl.
24. Water Resources of the State of New York, Part I, by George W. Rafter. 1899. 8°. 99 pp. 13 pl.
25. Water Resources of the State of New York, Part II, by George W. Rafter. 1899. 8°. 101–200 pp. 12 pl.
26. Wells of Southern Indiana (Continuation of No. 21), by Frank Leverett. 1899. 8°. 64 pp.
27. Operations at River Stations, 1898, Part I. 1899. 8°. 100 pp.
28. Operations at River Stations, 1898, Part II. 1899. 8°. 101–200 pp.

In preparation:

29. Wells and Windmills in Nebraska, by Edwin H. Barbour.
30. Water Resources of the Lower Peninsula of Michigan, by Alfred C. Lane.

TOPOGRAPHIC MAP OF THE UNITED STATES.

When, in 1882, the Geological Survey was directed by law to make a geologic map of the United States there was in existence no suitable topographic map to serve as a base for the geologic map. The preparation of such a topographic map was therefore immediately begun. About one-fifth of the area of the country, excluding Alaska, has now been thus mapped. The map is published in atlas sheets, each sheet representing a small quadrangular district, as explained under the next heading. The separate sheets are sold at 5 cents each when fewer than 100 copies are purchased, but when they are ordered in lots of 100 or more copies, whether of the same sheet or of different sheets, the price is 2 cents each. The mapped areas are widely scattered, nearly every State being represented. About 900 sheets have been engraved and printed; they are tabulated by States in the Survey's "List of Publications," a pamphlet which may be had on application.

The map sheets represent a great variety of topographic features, and with the aid of descriptive text they can be used to illustrate topographic forms. This has led to the projection of an educational series of topographic folios, for use wherever geography is taught in high schools, academies, and colleges. Of this series the first folio has been issued, viz:

1. Physiographic types, by Henry Gannett, 1898, folio, consisting of the following sheets and 4 pages of descriptive text: Fargo (N. Dak.-Minn.), a region in youth; Charleston (W.Va.), a region in maturity; Caldwell (Kans.), a region in old age; Palmyra (Va.), a rejuvenated region; Mount Shasta, (Cal.), a young volcanic mountain; Eagle (Wis.), moraines; Sun Prairie (Wis.), drumlins; Donaldsonville (La.), river flood plains; Boothbay (Me.), a fiord coast; Atlantic City (N. J.), a barrier-beach coast.

GEOLOGIC ATLAS OF THE UNITED STATES.

The Geologic Atlas of the United States is the final form of publication of the topographic and geologic maps. The atlas is issued in parts, progressively as the surveys are extended, and is designed ultimately to cover the entire country.

Under the plan adopted the entire area of the country is divided into small rectangular districts (designated *quadrangles*), bounded by certain meridians and parallels. The unit of survey is also the unit of publication, and the maps and descriptions of each rectangular district are issued as a folio of the Geologic Atlas.

Each folio contains topographic, geologic, economic, and structural maps, together with textual descriptions and explanations, and is designated by the name of a principal town or of a prominent natural feature within the district.

Two forms of issue have been adopted, a "library edition" and a "field edition." In both the sheets are bound between heavy paper covers, but the library copies are permanently bound, while the sheets and covers of the field copies are only temporarily wired together.

Under the law a copy of each folio is sent to certain public libraries and educational institutions. The remainder are sold at 25 cents each, except such as contain an unusual amount of matter, which are priced accordingly. Prepayment is obligatory. The folios ready for distribution are listed below.

No.	Name of sheet.	State.	Limiting meridians.	Limiting parallels.	Area, in square miles.	Price, in cents.
1	Livingston	Montana	110°–111°	45°–46°	3,354	25
2	Ringgold	Georgia Tennessee	85°–85° 30′	34° 30′–35°	980	25
3	Placerville	California	120° 30′–121°	38° 30′–39°	932	25
4	Kingston	Tennessee	84° 30′–85°	35° 30′–36°	969	25
5	Sacramento	California	121°–121° 30′	38° 30′–39°	932	25
6	Chattanooga	Tennessee	85°–85° 30′	35°–35° 30′	975	25
7	Pikes Peak (out of stock)	Colorado	105°–105° 30′	38° 30′–39°	932	25
8	Sewanee	Tennessee	85° 30′–86°	35°–35° 30′	975	25
9	Anthracite-Crested Butte	Colorado	106° 45′–107° 15′	38° 45′–39°	465	50
10	Harpers Ferry	Virginia West Virginia Maryland	77° 30′–78°	39°–39° 30′	925	25

No.	Name of sheet.	State.	Limiting meridians.	Limiting parallels.	Area, in square miles.	Price, in cents.
11	Jackson	California	120° 30′-121°	38°-38° 30′	938	25
12	Estillville	Virginia Kentucky Tennessee	82° 30′-83°	36° 30′-37°	957	25
13	Fredericksburg	Maryland Virginia	77°-77° 30′	38°-38° 30′	938	25
14	Staunton	Virginia West Virginia	79°-79° 30′	38°-38° 30′	938	25
15	Lassen Peak	California	121°-122°	40°-41°	3,634	25
16	Knoxville	Tennessee North Carolina	83° 30′-84°	35° 30′-36°	925	25
17	Marysville	California	121° 30′-122°	39°-39° 30′	925	25
18	Smartsville	California	121°-121° 30′	39°-39° 30′	925	25
19	Stevenson	Alabama Georgia Tennessee	85° 30′-86°	34° 30′-35°	980	25
20	Cleveland	Tennessee	84° 30′-85°	35°-35° 30′	975	25
21	Pikeville	Tennessee	85°-85° 30′	35° 30′-36°	969	25
22	McMinnville	Tennessee	85° 30′-86°	35° 30′-36°	969	25
23	Nomini	Maryland Virginia	76° 30′-77°	38°-38° 30′	938	25
24	Three Forks	Montana	111°-112°	45°-46°	3,354	50
25	Loudon	Tennessee	84°-81° 30′	35° 30′-36°	969	25
26	Pocahontas	Virginia West Virginia	81°-81° 30′	37°-37° 30′	951	25
27	Morristown	Tennessee	83°-83° 30′	36°-36° 30′	963	25
28	Piedmont	Virginia Maryland West Virginia	79°-79° 30′	39°-39° 30′	925	25
29	Nevada City: Nevada City Grass Valley Banner Hill	California	121° 00′ 25″-121° 03′ 45″ 121° 01′ 35″-121° 05′ 04″ 120° 57′ 05″-121° 00′ 25″	39° 13′ 50″-39° 17′ 16″ 39° 10′ 22″-39° 13′ 50″ 39° 13′ 50″-39° 17′ 16″	11.65 12.09 11.65	50
30	Yellowstone National Park: Gallatin Canyon Shoshone Lake	Wyoming	110°-111°	44°-45°	3,412	75
31	Pyramid Peak	California	120°-120° 30′	38° 30′-39°	932	25
32	Franklin	Virginia West Virginia	79°-79° 30′	38° 30′-39°	932	25
33	Briceville	Tennessee	84°-84° 30′	36°-36° 30′	963	25
34	Buckhannon	West Virginia	80°-80° 30′	38° 30′-39°	932	25
35	Gadsden	Alabama	86°-86° 30′	34°-34° 30′	986	25
36	Pueblo	Colorado	104° 30′-105°	38°-38° 30′	938	50
37	Downieville	California	120° 30′-121°	39° 30′-40°	919	25
38	Butte Special	Montana	112° 29′ 30″-112° 36′ 42″	45° 59′ 28″-46° 02′ 54″	22.80	50
39	Truckee	California	120°-120° 30′	39°-39° 30′	925	25
40	Wartburg	Tennessee	84° 30′-85°	36°-36° 30′	963	25
41	Sonora	California	120°-120° 30′	37° 30′-38°	944	25
42	Nueces	Texas	100°-100° 30′	29° 30′-30°	1,035	25
43	Bidwell Bar	California	121°-121° 30′	39° 30′-40°	918	25
44	Tazewell	Virginia West Virginia	81° 30′-82°	37°-37° 30′	950	25
45	Boise	Idaho	116°-116° 30′	43° 30′-44°	864	25
46	Richmond	Kentucky	84°-84° 30′	37° 30′-38°	944	25
47	London	Kentucky	84°-84° 30′	37°-37° 30′	950	25
48	Tenmile District Special	Colorado	106° 8′-106° 16′	39° 22′ 30″-39° 30′ 30″	55	25
49	Roseburg	Oregon	123°-123° 30′	43°-43° 30′	871	25
50	Holyoke	Massachusetts Connecticut	72° 30′-73°	42°-42° 30′	885	25

STATISTICAL PAPERS.

Mineral Resources of the United States [1882], by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1883 and 1884, by Albert Williams, jr. 1885. 8°. xiv, 1016 pp. Price 60 cents.

Mineral Resources of the United States, 1885. Division of Mining Statistics and Technology. 1886. 8°. vii, 576 pp. Price 40 cents.

Mineral Resources of the United States, 1886, by David T. Day. 1887. 8°. viii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1887, by David T. Day. 1888. 8°. vii, 832 pp. Price 50 cents.

Mineral Resources of the United States, 1888, by David T. Day. 1890. 8°. vii, 652 pp. Price 50 cents.

Mineral Resources of the United States, 1889 and 1890, by David T. Day. 1892. 8°. viii, 671 pp. Price 50 cents.

Mineral Resources of the United States, 1891, by David T. Day. 1893. 8°. vii, 630 pp. Price 50 cents.

Mineral Resources of the United States, 1892, by David T. Day. 1893. 8°. vii, 850 pp. Price 50 cents.

Mineral Resources of the United States, 1893, by David T. Day. 1894. 8°. viii, 810 pp. Price 50 cents.

On March 2, 1895, the following provision was included in an act of Congress:

"*Provided*, That hereafter the report of the mineral resources of the United States shall be issued as a part of the report of the Director of the Geological Survey."

In compliance with this legislation the following reports have been published:

Mineral Resources of the United States, 1894, David T. Day, Chief of Division. 1895. 8°. xv, 646 pp., 23 pl.; xix, 735 pp., 6 pl. Being Parts III and IV of the Sixteenth Annual Report.

Mineral Resources of the United States, 1895, David T. Day, Chief of Division. 1896. 8°. xxiii, 542 pp., 8 pl. and maps; iii, 543–1058 pp., 9–13 pl. Being Part III (in 2 vols.) of the Seventeenth Annual Report.

Mineral Resources of the United States, 1896, David T. Day, Chief of Division. 1897. 8°. xii, 642 pp., 1 pl.; 643–1400 pp. Being Part V (in 2 vols.) of the Nineteenth Annual Report.

Mineral Resources of the United States, 1897, David T. Day, Chief of Division. 1898. 8°. viii, 651 pp., 11 pl.; viii, 706 pp. Being Part VI (in 2 vols.) of the Nineteenth Annual Report.

The money received from the sale of the Survey publications is deposited in the Treasury, and the Secretary of that Department declines to receive bank checks, drafts, or postage stamps; all remittances, therefore, must be by MONEY ORDER, made payable to the Director of the United States Geological Survey, or in CURRENCY—the exact amount. Correspondence relating to the publications of the Survey should be addressed to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

WASHINGTON, D. C., *June, 1899.*

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